HIGH SCHOOL GEOGRAPHY

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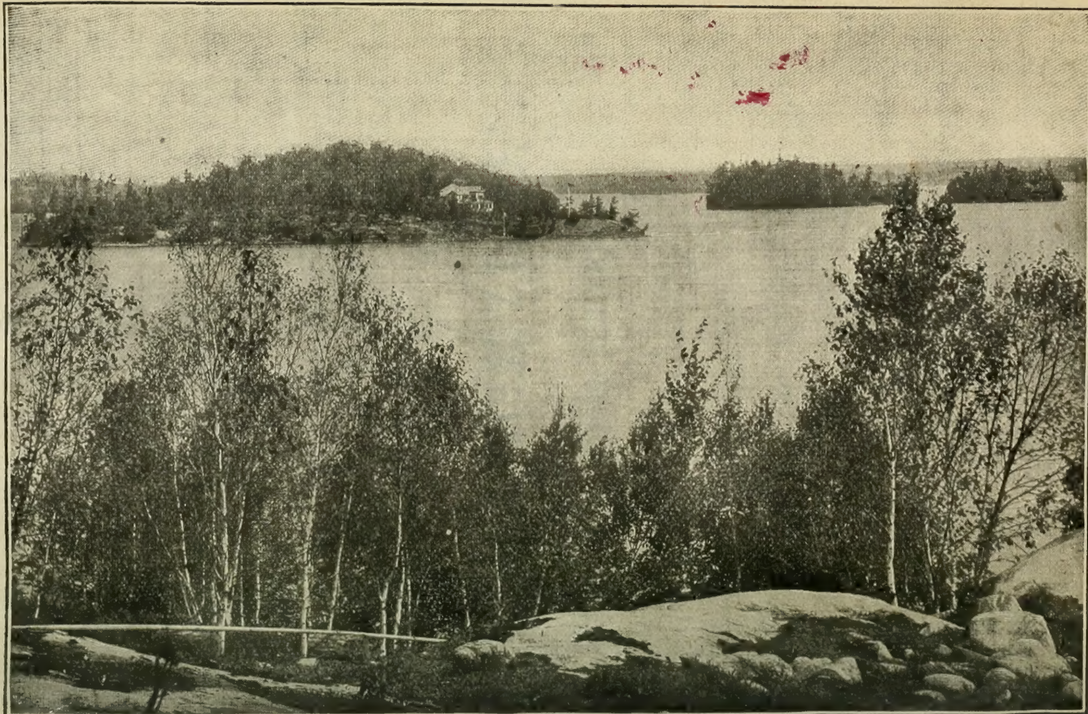

Glacial Islands in Lake Rosseau, Muskoka.

HIGH SCHOOL

GEOGRAPHY.

BY

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PREFACE.

Of late years the study of Physical Geography has made rapid advances; it forms part of the course of study in higher schools, and has its lectureships and professorships in various universities of the United States and Europe. It is recognized not only as an important study in itself, cultivating the habit of observation and of associating cause and effect, but also as an introduction, or rather an incitement, to the study of various sciences.

Physical Geography, "a description of Nature in what pertains to the Earth," is eclectic in character. Resting mainly on Geology, and only to a less degree upon Meteorology, it reaches out to Astronomy, to Mineralogy, to Chemistry, to Biology, and even to History and Political Economy.

The present book, while giving numerous facts, endeavors, in all the subjects dealt with, to keep principles steadily in view, to refer effects to causes, to follow causes to effects; to give theory as theory, and fact as fact. But a book alone is not enough; field work is a necessity; facts from the out-door experience of both teacher and taught are the very life of the subject. The features of the

surrounding country, the phenomena of air and sky that all know and speak of, experiments in the chemical and the physical laboratory along with its necessary adjunct, the stereopticon, must all be employed in the effective treatment of this highly important study.

The latest and best sources of information,—books, government reports, geographical magazines, publications of various scientific societies, &c.,—have all been consulted in the preparation of the following pages. The engravings, excepting a very few which have been taken from drawings, have been made directly from photographs, or from authentic reproductions of photographs, and where the subject permits, are Canadian.

Books and publications dealing with the separate features of Physical Geography are very numerous. The Ontario Education Department publishes a comprehensive list of the latest and best.

The chapters on LIFE and THE HEAVENS have been written by Mr. G. A. Smith, B.A., of the Jameson Avenue Collegiate Institute, Toronto; the chapter on COMMERCIAL GEOGRAPHY is by Mr. Wm. Scott, B. A., Principal of the Toronto Normal School. Both gentlemen, within a necessarily confined space, have done their work in a manner worthy of all praise.

G. A. C.

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CHAPTER I.

BUILDING UP OF THE EARTH.

STRATA.

ROCK. Everywhere we see the land surface of the earth covered with a fine loose material called *soil*, from which vegetation springs, and which consists of mineral, or inorganic, matter, together with a varying but small percentage of organic matter—the latter coming from the decay and waste of plants and animals, the former from the decay of the rock beneath. For everywhere below the soil, and at varying depths, is found the firm, hard mass that we call the solid rock.* It comes into view along the course of rivers and on the shores of lakes and seas, while in mountain regions it forms peaks often thousands of feet in height.

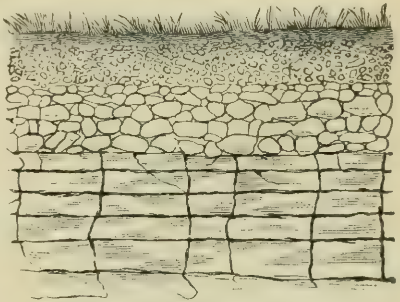

FIG. 1. Bed-rock changing into soil.

STRATIFIED AND UNSTRATIFIED ROCKS. Where the rocks are thus exposed they are seen to occur in two different forms—in layers or beds, hence called *stratified* † rocks, and in irregular shapeless masses, or *unstratified* rocks. The layers, or strata, of the former by no means always lie horizontally; they are often tilted up, standing on edge, curved, twisted and bent in a most remarkable manner, though the surface of the soil may be level. Thus, while in all the south-western

* Geologists apply the term "rock" to all mineral matter,—soil, sand, coal.
† From the Latin *stratum* (pl. *strata*) a bed.

portion of Ontario the strata are horizontal, or nearly so, in the north-eastern and northern portions they are quite different, being curved, twisted, and bent to a very great degree. On the other hand the unstratified rocks have the appearance of forcing their way up from below through the stratified rocks, from which they also differ in internal structure and composition. Of these the most familiar is granite in its different varieties, which, though plentiful in the mountain regions of Canada, occurs only sparingly in Ontario,—along the northern shores of Lake Huron and Lake Superior.

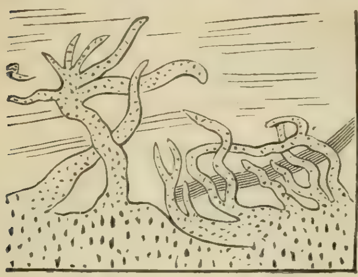

FIG. 2. Unstratified rock piercing up into stratified. Also Figs. 6, 11, 25.

HOW STRATIFIED ROCKS WERE FORMED. During a rainstorm little pools of water are formed here and there which, on drying up, leave behind thin sheets or layers of mud, that often curl up and split into still thinner sheets as they lose their moisture; little streams, too, rush down the hillside scoring channels in it and spreading out their load of gravel, sand and mud at its base, layer upon layer, or carrying it to some larger stream, which bears it away only to drop it in the quieter waters of some pond or lake or shallow along its course, or in the sea itself. And thus in the course of time this ever recurring dropping of *sediment* must fill up pond and lake and shallow, and what was once a level expanse of water will become a level expanse of land, with only a stream running through it; and should this stream be wanted for navigation it has to be kept deep by continual dredging to remove the sediment that will gather at the bottom.

Every river and every brook in our Province shows this work going on before our eyes. Now, if we should dig into this *alluvial* ground, as it is called, it will be found to lie in layers just as we should expect. For we see that after a heavy rain, or when the snow melts rapidly in the spring,

the water in the streams is very muddy and has a great deal of coarse material of different kinds in it; and so what falls to the bottom from such water will be greater in amount and somewhat different in character from what falls out after a moderate rain, or during a time when there is no rain, and these differences will be seen in the different layers.

If, again, we look at the beaches along our lakes, or still better, along the sea shore, we see how the waves as they dash upon them, spread out fine sand here, coarse sand there, gravel in one place and pebbles or large stones in another, and mingle all together in still another; and when we dig down and find layers of these materials following each other as far as we go, we know the waves have done it all.

Down by the sea, too, in quiet bays and nooks where the shore around is of soft material, the retreating tide leaves great expanses of mud bare for hours; crows, snipe, cranes and other birds come thither hunting for marine worms, mussels or stranded fish, and the mud hardening in the sun, retains their foot-prints; successive high-waters will gradually fill the tracks up till all trace of them disappears. But they are not lost; for if some of this mud should be removed and dried it will split into very thin layers, each being the sediment that one high-water has left behind; then the bird tracks will again be seen.

FIG. 3. Sun cracks and tracks of reptiles in sandstone.

The stratified rocks, wherever we see them, present the very same appearances as do these beds of sediment or the beaches along the shore:—Sandstone looks like beaches turned solid, its finer varieties, as we often see in the flagstones of our cities, showing the very same curious wavy markings, and curves, and bedding-lines, as are being made by the water on our beaches to-day; slate-stone and shale split into thin leaves just as does the dried mud of

pools, or of the tide-swept flats of the sea-side; and both sandstone and shale contain shells, and show foot-prints of birds or other animals, or the pittings made by rain as do our modern sand and mud.

FIG. 4. Pittings of rain in sandstone.

From these considerations and many others, it is felt to be quite certain that stratified rocks were formed from the sand that water heaped up and spread out along sea-beaches, or from finer material that was borne from the shores far and wide into sea and lake, and that slowly sinking to the bottom, gradually built up there these vast beds which are met with all over the world, the loose sand and the soft mud alike, partly through pressure, partly through chemical action, finally hardening into stone.

LIMESTONES, OR CALCAREOUS ROCKS. Not all of the rock, however, that was formed in water, is of earthy material such as mud or sand. Soundings in many parts of the sea bring up a grayish kind of mud, or ooze, that the microscope shows to be composed almost wholly of the calcareous, or limy, shells of minute little animals called Rhizopods, that live at the surface of the sea where their food is, and on dying sink to the bottom. Chalk, which is a kind of limestone, and forms so many of the downs and cliffs of England, is shown by the microscope to consist almost wholly of the minute shells of the same kind of little marine creature that gives rise to the ooze at the bottom of the sea to-day.

In our warm shallow seas the coral animal, or polyp, is forming from the lime it gathers from the water, a stony house around itself,—a house that on the death of the polyp becomes the foundation for another to build on, till at length such huge masses of coral as the Great Australian Barrier Reef are formed. But only the outer part is rough and full of tubes and pores; for the salt water gradually

softens the old coral and melts it together into a very firm mass of stone. Coral sand and coral mud build up great masses of limestone in the deeper water to which they are borne, or around the coral reefs themselves. Other sand and mud, not of coral, sometimes mingle with these and then the limestone is impure. Or the coral sand and dust may be blown inland into great ridges, and there becoming solid through the action of rain, form fine limestone,—just such as the people of Bermuda cut out of quarries with saws, so soft is it when not exposed to the air, in order to form building stone for their gleaming white houses.

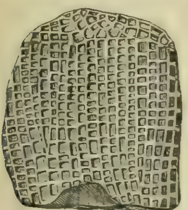

FIG. 5. A fossil coral, *Favosites*, Niagara.

North of our Lake Erie limestone largely made up of coral exists in abundance; and in many other places, Niagara, for instance, and Guelph, the limestone is full of the limy coverings of other sea creatures, while other limestone shows little or no trace of remains of sea creatures, but was doubtless formed by chemical action which caused the lime in the water to settle to the bottom. (See page 180).

Still other kinds of rock, such as salt and gypsum, both the result of chemical action in the water, are found quite abundantly, even in Ontario, but far more abundantly in some other countries.

UNSTRATIFIED ROCKS. As has been said. unstratified rocks are quite different from the stratified rocks; they are composed of different matter; they all have a glassy or *vitreous* look, as if they had been melted; in mines or quarries or hillsides

FIG. 6. Dyke of red granite piercing gray granite. St. John, N. B. Also Figs. 2, 11.

they are seen penetrating in among other rocks and looking like branches of trees or little streams or veins,—just as if some molten matter had gushed up from below filling up any cracks it could find in the rocks and then hardening into stone; on the bare upper surface of the rock these look like great seams, sometimes even standing out above the other rock on account of being harder and so not easily crumbled away by frost or other destroying means. Then, too, they are seen in great solid masses, not beds, rising high into mountains and, where bare of trees, white and glistening as the weather-worn granite that gives the name to the *White Mountains*, or forming great rounded ridges as in Nova Scotia; or again standing out from a surrounding level country in single black masses such as the Montreal or Belœil Mountain in Quebec, or in long dark narrow ridges such as the North Mountain by the Bay of Fundy in Nova Scotia.

Now, science tells us that only great heat can produce the glassy, or vitreous, appearance in these rocks, and only molten matter could be rolled together in these shapeless masses, or well up into the cracks or openings where we find it. granite, lava, trap

THE HEAT OF THE EARTH.

But it may be asked "Where could the heat that thus melted the rocks, come from?" We know that great heat must in some way exist in the earth, for volcanoes show it, and hot springs such as the Geysers in Iceland and elsewhere; and the deeper that mines are dug the greater the heat in them becomes.

Some scientific men think that the enormous pressure of the rocks above on those below causes the heat,—for pressure does produce heat. But this makes us ask where the rocks came from,—what caused them?

THE NEBULAR THEORY.

We know that some substances very readily evaporate, that is, turn into vapor,—ether, for instance, or water; indeed almost any substance when intensely heated gives off vapor, the different metals very readily do so. Now, if the rays of light that are given off from intensely heated things, are allowed to pass through a prism, or *spectroscope*, they will show different colors and markings, the *spectrum* of each

substance being in color or in markings, or in some other way, different from that of all others. In this way it has been found out that the sun and those planets and stars that shine by their own light, are composed of the same materials as the earth.

Astronomers have long known that in the heavens there exist immense masses of thin fiery vapor, "glowing gas," that they call *nebulæ*, and the spectroscope shows that this vapor is the vapor of the very same materials as those that compose the earth. So it is thought that the sun itself, with the earth and all the other planets that revolve around the sun, was once a great nebula which in the course of countless ages separated into smaller masses, and that each of these on cooling down became a planet, some, such as our moon, having now lost all of their heat, others being in different stages of cooling.

In the case of our earth the cooling vapor gradually became a fiery liquid, and further cooling covered this with a crust,—the first rock, while above it was the atmosphere, far deeper than it is now and filled with gases that it would be impossible for us to breathe; but from this atmosphere came in later and cooler ages the rains which, falling on that early rock and dissolving some of it, made the first mud that formed the first stratified rock. Such is the *Nebular Theory* of the origin of the earth according to our astronomers.

But we may be sure that the first crust of the earth was broken through again and again and flooded by the fiery mass below it, and that the cooling process still continued, and still continues to the present day. Many scientific men believe that the interior of the earth is still a liquid mass; that the granite rocks, which in some mountainous regions are known to be slowly rising, are only this liquid mass still pushing its way in places toward the surface of the earth, but becoming cold before reaching it; and that the lava * of volcanoes is the fiery mass itself poured out on the surface of the earth and there cooled.

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*Both granite and trap are called *igneous* rocks because both have cooled from the molten state; but to distinguish one from the other the former is called *plutonic*, the latter *volcanic;* both are crystalline but the crystals of the plutonic rocks are very much coarser than those of the volcanic rocks, and the latter are the more glassy.

Others say the earth is solid and very rigid; otherwise it could not keep its shape under the great strain of the attraction of the sun and moon. Still others think the outer crust rests on a molten layer, beneath which all (the greater part of the earth) is solid. Pressure causes the solid core; cooling, the crust; the liquid being transitional.

METAMORPHIC OR CHANGED ROCKS. While the stratified rocks are all alike, lying in layers, they differ very much in color, in fineness of grain, in hardness, in the material of which they are composed, and in many other ways. But there is one kind of such rocks that in some respects resembles the unstratified rocks, especially in their crystalline appearance. They are never found on top of other stratified rocks, but always under them; and in mountain regions they burst up through them to form some of the wildest of mountain scenery.

FIG. 7. Nearly horizontal strata resting on disturbed metamorphic rock, both showing *faults*. (See "Archæan Period, page 17, and Fig. 17.)

Then when they are found along with granite or other igneous rocks in mountains or other hilly districts, they lie just on top of the igneous rocks; in the more level regions they are seen almost everywhere to have veins or seams of igneous rocks branching through or piercing them in all directions. This latter is the case in Muskoka and indeed in almost all the eastern half of Canada,—the region bounded on the west and south by that great chain of lake and river stretching from the Gulf of St. Lawrence to the Arctic Ocean.

Now we know that in the laboratory the character of stone can be changed by exposing it to great heat along with moisture; and we see that these crystalline rocks are always found where great heat has been, and moisture too,—for their stratification shows they must have been formed from the sediment of water. Therefore it is believed that after these rocks had been laid down by the water in layers of vast extent and great depth,—sea-animals living in them

and on dying leaving their shells to be buried ever deeper in the mud,—the molten mass welled up again from below, and forcing its way up into and often through the half-hardened and moist mass above, changed its character almost completely, at the same time disturbing the layers, twisting them and throwing them into every possible shape.

Thus sandstone has been changed into the dull-white, very hard glassy stone called *quartz;* shale, a stone formed from fine mud in thin layers, is turned into *slate;* and limestone has become *marble*, which sometimes shows remains of the shell-fish that lived in it when it was only mud. And so it would seem that these metamorphic rocks were probably the first formed stratified rocks in the history of the world; though, as heat still exists in the earth, and molten matter is still forcing its way upward, it is probable that metamorphic rocks are still being formed where the molten mass comes in contact with other rocks.

ELEVATION OF STRATA. In a former paragraph it has been stated that while in some places the strata are horizontal, in others they are tilted up in various degrees, even standing on edge, or forming great arches, or crumpled up in folds large and small. What

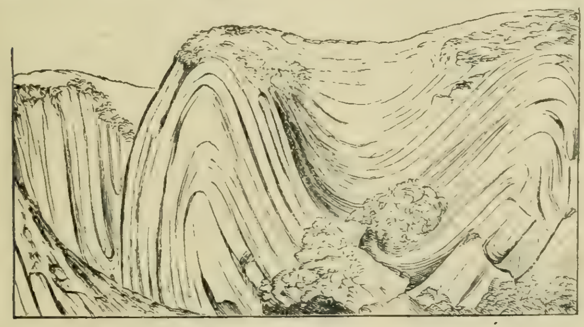

FIG. 8. Folded and arched strata. Also Fig. 18.

has caused all this? We have seen that the strata must have been originally laid down practically flat on the bottom of the sea, or at most somewhat gently sloping, for the sea-floor always does slope away from the land.

The ground seems to be in a state of movement everywhere, though the motion in most places is imperceptible. The spot where the first missionaries to Greenland built their houses, is now many feet under water; near Fort Lawrence, at the head of Cumberland Basin, off the Bay of Fundy, the remains of a forest are seen just above low-water mark; at various places along the basin of the St. Lawrence and the Great Lakes, old beaches occur in such positions as seem to prove that the land in this part of Canada is rising. Such changes of surface cannot take place unless the rock upon which the surface rests changes too.

Volcanic regions are known to be very unsteady:—parts of Italy have risen and sunk again more than once within historical times; the coasts of Peru and Chili are subject to great changes of level; and some scientific men think that the very numerous volcanoes in the Indian Archipelago poured out so great a quantity of lava from beneath, that the land that once connected these islands with Asia was undermined and settled down. and thus let in the ocean, forming the shallow sea that now exists there.

Then too, it is known that vast beds of sediment are forming on the sloping sea-floor in the neighborhood of the continents, and it is thought the weight of these and of the sea above acting on the inclined strata beneath, exerts an enormous pressure sidewise, and the soft and yielding strata giving way to it are forced upward, and in the movement become bent and deformed.

But whatever part volcanic action or pressure from beds of sediment may play in producing movement in the strata of the earth, they cannot account for the movements everywhere :—The valley of the St. Lawrence is far removed from the region of volcanoes, and it has in most places no great beds of sediment beneath its waters. There must be other causes.

Now, whether the nebular theory of the earth is correct or not, certain it is that great heat exists within the earth, and that this heat is slowly passing off into space: the earth is gradually getting cooler. And all bodies grow smaller as they cool. If the cool outside of our earth is now resting down on the hot inside, when this hot inside

gets cool it must get smaller than it is, and so either it must shrink away from the outside or the outside must keep settling down upon it. If the outside shell were composed of rocks all of the same intense hardness and were everywhere thick enough, then the mighty arch that it would form might be able to stand the awful strain of the attraction of gravity, and remain a great shell around other shells further within.

But the strata are not all intensely hard; many indeed are very soft, and so could not stand the strain of gravity were they ever so thick. They must, therefore, as the inner part of the earth cools keep settling down on the cooling mass; but in doing so, the shell must in some way get smaller, otherwise it could not settle down. If we press the two ends of a thin, narrow piece of wood toward one another, the piece of wood will bend, or form a fold, or more than one fold if we prevent the first one from getting large; and if the pressure is continued too long or is too violent, the wood will break, more especially if some part of it is thinner than another.

Strata will act in just the same way. The weight of the strata, *i.e.*, the attraction of gravity, causes so great a pressure everywhere that the strata cannot stand it, and so, like the thin piece of wood, they will rise in a great fold or a succession of folds, some large, some small. Some folds will have a span of many miles, as is often seen in mountainous regions, some of only a few yards. In this way the shell becomes smaller, and so can readily settle down upon the shrinking mass below.

Sometimes, as we see in the case of the piece of wood, the strata in being thus pressed will break, not all parts being equally strong. Then one part will settle down and leave the other high in the air, or even by its greater weight force the other to rise higher still. These breaks, where sinking down or sliding up occurs, are called "*faults*," and are very common. So, too, we may readily see that though no faults may occur, the strata may be broken and shattered by the pressure, and thrown into every imaginable position, as is so often revealed in the rocky walls of deep chasms.

And though both volcanic action and the pressure

of great beds of sediment on the sloping bottom of off-shore waters undoubtedly do disturb the strata in their neighborhood, yet this cause, the contraction of the earth, will account for all the movements of the earth's crust everywhere. It tells us how strata that were laid down horizontally or nearly so, are seldom found in the same position now; it tells us what is the origin of mountains, and how they can still grow, as we know the Rocky Mountains, the Alps, the Himalayas and others are growing; it may even explain, as many think, volcanoes and earthquakes. It is the theory held by all scientific men.

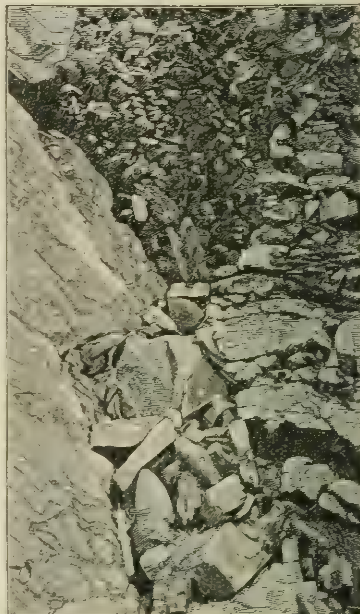

FIG. 9. Fault as seen in nature: metamorphic rock (gneiss) on the left, Cambrian strata on right much broken by the "down-throw." Quebec. See ideal fault, Fig. 7. (Reduced from "Geological Survey of Canada.")

And so it has ever been since the first crust over the molten mass was formed, and the first stratum laid down from the waste of that primitive igneous rock. The shrinking earth gradually forced some of the new formed strata out of the water, when they in their turn supplied the material for still newer strata: these again in whole or in part, were forced upward, while the former ones sank once more beneath the sea to receive new beds of sediment upon them. And thus the process went on,—alternate rising and falling as the earth got smaller through cooling, till at last after the lapse of countless ages the earth as it now is was built up.

LIFE ON THE EARTH.

But the study of the rocks has an interest for us beyond their mere origin, their formation and their use—a deeper

and more important interest—for it reveals to us the story of life on the earth from its lowly beginnings in humble sea-weeds or in a mass of gelatinous matter that wove for itself a limy covering from the waters of the sea, to its crowning development in *Man* who claims kindred with still higher beings.

FOSSILS. In our ponds and lakes we see pieces of wood, large and small, becoming "water-logged" and sinking; land animals getting drowned, and fishes dying; land-shells washed down the hill-sides into the water, and river-shells hurried along by the swift currents of the streams—all finally buried beneath the accumulating sediment. And such, we may be sure, has always been the case wherever and whenever there was water to run, sediment to deposit, or plants and animals to bury. No wonder then that in the stratified rocks we come across the remains of plants and animals, *fossils* we call them, now only stone, or only impressions or casts made when the enclosing rock was soft sediment, countless ages ago.

SPREAD OF LIFE. If the climate of Iceland and Norway and Great Britain were to become many degrees warmer than now, it would not be long before plants that grow only in the West Indies, and fishes that swim only in the West Indian waters, would be found without man's aid living and thriving in and around these countries whose coldness alone now keeps them away. For we all know that the Gulf Stream and other oceanic currents that set northward from the warm regions of the south, carry with them fragments of southern plants and fruits and seeds, and throw them ashore on northern lands where they can only perish; and we know, too, that the young of very many kinds of shell-fish and other low forms of marine life, swim about freely before they become fastened to a particular spot; and these little swimming creatures are carried by the ocean currents far and wide in regions suited to their existence.

If the currents thus spread life now when there is so much land on the earth to interfere with or check their course, what must they have done when the land was far less than now, and when they could move with so little obstruction! And then, too, on the land. How is it that

the maple tree is found in the length and breadth of America wherever it can possibly grow? We have only to look for an answer to a maple tree when it is shedding its multitude of ripened seeds on a windy day. Thus these two causes alone, even were there no others, would spread the same types of life over widely extended regions.

PROGRESS OF LIFE. More important to us still is the fact that the fossils reveal to us the progress of life, both animal and vegetable, on our earth. They cannot, indeed, tell *how* life began, but they show us its first and lowly beginnings in water and on land, and its gradual development into the highest forms. But yet this history of life is not perfect or complete; for there have been so many and such irregular upheavals and depressions, with altering of strata, so much destruction by wind and rain, by heat and frost, and by running streams and beating waves and other agents, that great gaps occur in the record of life as enclosed in the rocks—gaps that probably will never be filled up. We should like very much to know if there were really any land plants or land animals in late Archæan times; or what kind of creatures inhabited the great belt of land that once united the British Islands with North America and that sank again leaving the high ridge at the bottom of the Atlantic of which the "Banks of Newfoundland" form a part; or if that great expanse of land which, as many geologists hold, once united Southern Africa with the East India Islands and Australia, had any of those queer animals that are now found only in Australia; or how it happened that Australia has no native land animals of the highest kind, the *mammals*, except the lowest of that kind—*marsupials*.* (See page 345).

Yet with all the gaps, and with so many questions left unanswered, the rocks by their fossils show a steady advance of life toward the higher forms of to-day. For each successive stratum, along with low or the lowest kinds of animals or plants, reveals the existence of types of higher life than the stratum below possessed.

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*Animals that, after the young are born, carry them in a pouch or large fold of the skin.

For a fuller treatment of the "Progress of Life," see Chapter VIII.

DISAPPEARANCE OF FORMS OF LIFE.

But the rocks show, too, that types of life that were so marked a feature of one age, more or less suddenly disappeared, not, however, before the type that was to be so important in the next age had come in. The strange fossil that looks like a closely coiled, wrinkled ram's horn (hence called *Ammonite*), is met with only in the Cretaceous Era, and the *Trilobite* (Figs. 16, 19), in various forms, is found throughout the rocks of the longest of the periods of earth's history, and nowhere else,—for when a species of plant or animal once disappears it never returns. Those hideous reptiles, the *Deinosaurs* (Fig. 27), monsters of appalling size, have all gone, and in our swamps and peat-bogs to-day we dig up the bones of those more peaceful, but still huge beasts, the *Mammoth*, so lately perished that even its flesh has been found preserved in the frozen river-gravel of Siberia. Nature seems to have been prodigal in kinds of life, of which the still living ones form only a very, very small portion.

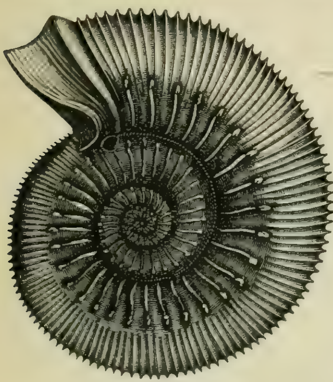

FIG. 10. An Ammonite.

What caused this disappearance it is hard to say. We know that new mountain ridges were always rising somewhere, which would change the winds and so bring a different kind of climate and temperature on land and sea in which the old creatures could not well live; and the new land must have changed the course of currents, as we have seen above, and so brought water not suited to the old life; the great volcanic outbursts by pouring their lava and ashes into the sea and filling the air with their deadly gases, as they have done and are doing even in our days, must have caused destruction far and wide in sea and on land, as they do still. These, without doubt, are some of the causes that must have had effect on the life of other days, however many more there may have been.

SUCCESSION OF STRATA. In the walls of the gorge of the Niagara River we can plainly see that the strata composing them are not all of one kind; and so, too, the strata around Guelph and Galt differ from those in the region of Kingston. Now, it is evident that the strata of the walls of the Niagara gorge lying lowest down were formed before those above them; and where in traversing the country we see the strata change character, and one stratum passing under the other, we know that the latter was formed last, however much higher the former may be in places. But when the strata lie in regions remote from one another, such as British Columbia and Nova Scotia, or where in mountain regions they are broken up or contorted or in part worn away, it is much more difficult to say which were formed first. The character of the fossils will, however, to a great extent determine this. If the fossils of one region show a higher type of life than those of the other, the strata of the latter will have been formed first.

PERIODS IN THE HISTORY OF THE EARTH.

The occurrence and disappearance of fossils as just stated, has led geologists to recognize four, or even five, great periods in the history of life on the earth, though other circumstances, notably the great disturbances of the position of strata, have lent their aid to the same end.

The first period is usually called the Eozoïc, *Dawn of Life*, or Archæan, *Beginning*, Period;* the second is called the Palæozoïc or *Old Life* Period; the third, the Mesozoïc or *Middle Life* Period; the fourth, the Cainozoïc or *New Life* Period. But the great number of different kinds of strata, each with some particular fossil all its own, has made still other names necessary. The next smaller divisions are commonly called *Eras*, such as the Cambrian Era, or often *Systems*, while still smaller divisions are named *Series*, as the Niagara Series. See Plate II.

TIME IN GEOLOGY. There is no agreement among scientific men as to the lapse of time since the first strata were laid down. Sir Charles Lyell, by estimating the cubic contents of the Mississippi delta and the amount

*There is no uniformity among geologists in the use of these names: *Period, era, system, series, group*, etc. The meaning here given is that of Sir J. W. Dawson in his Handbook of Canadian Geology.

of sediment brought down by the river in twenty-four hours, thought that at least forty-five thousand years would be required to build up such a delta. Others make a lower estimate, but all agree that time in the history of the earth cannot be reckoned by years, or centuries, or millenniums, but by ages.

EOZOÏC PERIOD OR ARCHAEAN. The rocks of this "Dawn of Life," or "Beginning Period," underlie all other stratified rocks; they are the foundation strata upon which all other strata of later times are built, while they themselves must rest upon the primæval crust of the earth, from which the sediment came to form them. They are all crystalline, and often, especially in the lowest,

FIG. 11. Archæan gneiss in foreground, cut from right to left by a broad vein of white mineral, both being cut by a broad dyke of igneous rock which sends off a narrower dyke in the right foreground. (Geological Survey of Canada.)

or Laurentian, beds so much altered in their character by the heat that it is impossible to distinguish them from igneous rocks.

They are never found lying horizontally, but are crumpled and bent and folded to an extraordinary degree, while veins*

* *Veins* are fissures in the rock filled up with mineral matter dissolved from the rocks by water; while *dykes* are fissures filled by igneous matter from below.

of different minerals pierce them in all directions, and dykes of igneous rock traverse them from bottom to top, and often stand out like a wall above the surface, their hard material being not so easily crumbled away by frost and rain and sun as are the rocks through which they have pierced.

These Archæan rocks—the underlying ones being called by Canadian geologists, *Laurentian*, and the upper ones, *Huronian**—form the surface rocks over a vast area in Canada (see Plate I. and Fig. 14), while in other parts of the world they occur only in strips or patches, as it were. But wherever they are found they abound, especially the Huronian, in useful minerals, as if in compensation for the rugged, uninviting character of the country they form. The iron, copper, and silver mines of Ontario are all in the Archæan rocks, which form our roughest districts.

The most characteristic of Archæan rocks is called *Gneiss*—a crystalline rock, usually pinkish in color, with bands of dark mica running through it. Another rock very like Gneiss, and called *Schist*, contains much more mica and splits readily into thin leaves, thus showing more clearly its stratified character.

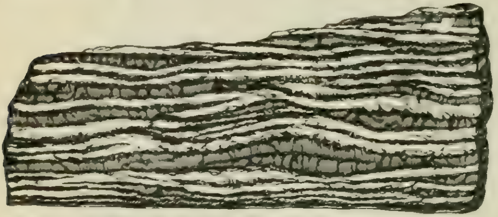

FIG. 12. A bit of banded gneiss.

The Life in Eozoïc times was very scanty. No fossils at all have been found in the lowest beds; either the heat of both land and sea was too great in those remote ages to permit of any kind of life, or if life did exist all traces of it were destroyed by the changes the primæval strata underwent. But the middle beds give what many geologists believe to be the fossil remains of the earliest form of life on earth—a coralline creature, whose soft parts are replaced in the fossil by a mineral dissolved from the limy covering.

Perhaps there may have been other life beside this *Eozoön*, for the beds of graphite,† which are common in

* From being found most characteristically, the first in the *Laurentide* mountains, and the second on the north of *Lake Huron*.

† The "lead" of lead pencils. *Eozoön*, "Dawn Animal."

Archæan rocks, may be only beds of seaweed transformed by the great heat into their present state; and the beds of crystalline limestone, which are also common, may be only old coral reefs.

FIG. 13. The Eozoön. The white parts were the cavities occupied by the soft portions of the living animal, now filled with a white mineral.

These Archæan rocks must have been laid down under water and therefore must have been in horizontal or nearly horizontal beds; but their crumpled appearance and the fact that the newer strata, for which they furnished the material, do not lie *conformably** upon them, shows that there must have been a great disturbance of the earth's crust before the Archæan strata rose from the water, a disturbance that not only crumpled the soft strata, but forced out of the water so vast an area as we have here in Canada. Nor, although this area may have been larger than it is now, did it ever wholly sink again, for all the later rocks only skirt its edges, never lie in patches great or small on top of it.

And so the Muskoka region and "New Ontario" have an interest for us all their own, not arising from their ruggedness or their peculiar scenery, but from the consideration that here "dry laird" had its birth.

PALAEOZOÏC PERIOD. The period of "Old Life" followed on the close of the "Dawn of Life." It was an inconceivably long period, during which the dry land was greatly increased on the earth and new forms of life, and ever higher ones, on land now as well as in the sea, arose and disappeared, leaving the record of their existence,

*That is, their beds do not lie in the same position. Figs. 7, 17.

sometimes only a meagre one, buried in the rocks. In Ontario no rocks of the succeeding periods exist, and of this period only those of the first three divisions are found—the Cambrian, the Silurian, and the Devonian or Erian. Like the Archæan rocks when once these rose above water they never sank again. Indeed, excepting in the Maritime Provinces, the prairie region of the West, and in districts on the Pacific coast, no other stratified rocks but these and the Archæan are met with in Canada. Thus we live in the oldest region of the earth.

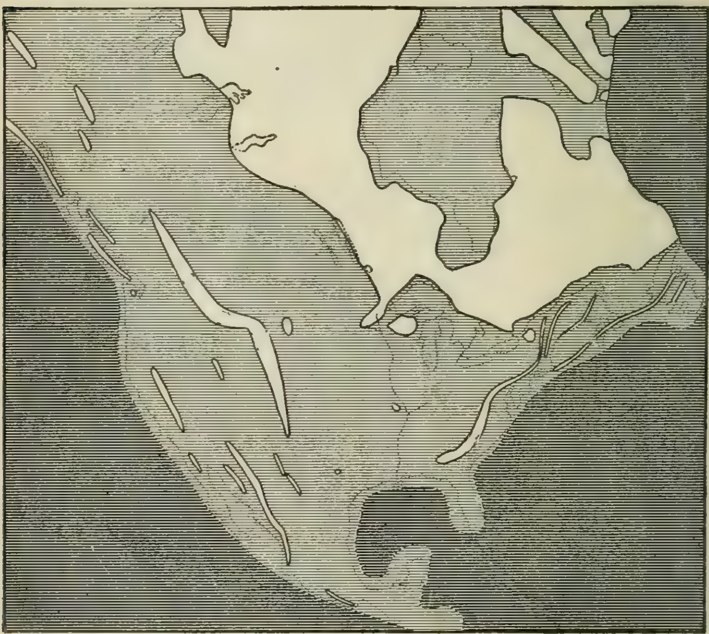

FIG. 14. The Archæan Continent. North America in outline, the white portions showing the regions of Archæan rocks, viz.: Canada north of the Lakes and the St. Lawrence, and the mountain chains east and west. (After Dana.)

The region of old Archæan rocks in North America, as the map shows us, already in those ancient days marked out the continent. How high that land rose above the

sea we cannot tell, but wherever it existed it supplied the material from its waste for the formation of new strata in the shallow waters beneath which it dipped. These first new strata, the Cambrian, skirt the Archæan rocks like a beach or shore; and when they in their turn rose above water they helped to supply material for still newer strata, the Silurian, farther away from the Archæan rocks, and skirting the Cambrian as the Cambrian do the Archæan. Then, following the rising of the Silurian strata, came the Devonian or Erian—which were still farther removed from the Archæan, and still farther built up the land-area of the earth. Above these last lie the great and important series of rocks known as the *Carboniferous* rocks—the rocks that furnish nearly all the great coal fields of the world except those of Western Canada; and the period closes with the Permian rocks. See Plate I. and Plate II.

DIFFERENCES IN STRATA.

It must not, however, be thought that all the rocks of each of these great eras are now out of water or were ever all out of water. For only a part of the new-formed strata rose; the rest was still left beneath the water to receive new beds of sediment from the new and old land alike—beds that, from the new conditions under which they were formed, had features all their own, differing very much from the beds below them.

Nor must it be thought that all the rocks of each era, or of each sub-division of an era, are of the same character. A little knowledge of the shores of our lakes and seas shows us that while in one place there is a long stretch of fine sand extending far out beneath the water, an inviting place for bathers, a few hundred feet or yards away the beach is a mass of loose cobble-stones or mingled sand and stones, and farther off in a little shallow cove there is only a deposit of mud with its growth of weeds and water grass, where bathers will not go. Now if these should sink beneath the water, and, after receiving deposits of new material upon them, in some future age should rise again, there would be sandstone and conglomerate* and shale, all lying close together and all formed at the same time.

Moreover, each of these would have some fossil found in itself alone, in addition to a fossil found in all three. For

* Rock composed of pebbles, cobble-stones and sand cemented into a mass. Fig. 33.

if on a beach of our Maritime Provinces we turn up one of the cobble-stones, we shall be almost sure to see some insect or other small marine creature hurrying in alarm to hide itself away from possible danger: it is a little creature that we may search for in vain in the sand or in the mud; but in the sand we shall find the clam (the *mya*) buried just at the bottom of the little round hole through which it thrusts its long siphon to suck in its food when the tide flows over it. Nor will the clam be found in the muddy bottom; still this latter will have its own animals which feed on its weeds and grasses, and which could not live in the other places. But the hard, strong-shelled little periwinkle is everywhere, clinging to the rocks and cobble-stones, trailing over the sand, or blackening the dead body of some fish, which, coming to seek its food among the weeds and grasses of the little cove, got entangled and was left by the retreating tide to die and be devoured by those voracious little gastropods. We need not wonder, then, if the varied rock formed in future ages from these beaches will tell the story of the varied life that belongs to them to-day.

So in those old Palæozoïc days, and in every age since, wherever sea existed and plants and animals lived and died, the conditions must have been the same as now. For in Cambrian and Silurian and Devonian rocks there are sandstones and conglomerates and shales with their own fossils and fossils belonging to all. From one of the bridges that span the Grand River at Galt the bed rock of the stream is seen to be pitted with holes, some large enough to take in the clenched fist. They are the holes from which the flowing water or rushing ice has forced the fossil casts of a shell-fish* that is found only in the peculiar cream-colored

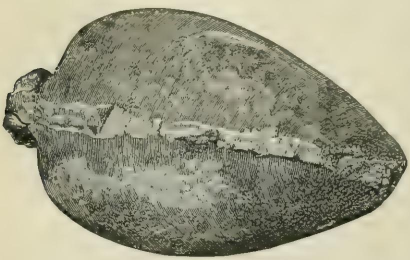

FIG. 15. The "Megalomus Canadensis," Galt; ¼ natural size.

*The "*Megalomus Canadensis;*" a bulky fossil not unlike the clenched fist in form and having its living counterpart in the shell fish, often called in Nova Scotia

limestone rock of this region. But the *trilobite*, a small *crustacean*,† is met with throughout the whole range of the Palæozoïc rocks.

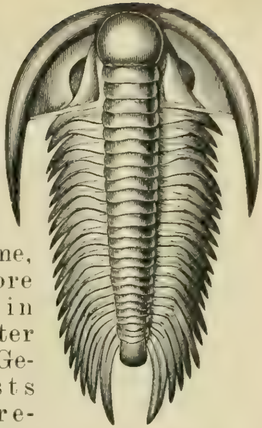

FIG. 16. A Cambrian Trilobite.

CRUST MOVEMENTS IN PALAEOZOÏC TIMES.

The progress of the earth was rather slow during the early ages of Palæozoïc time, but more rapid in the later ones. Geologists have remarked that the Palæozoïc strata everywhere, except in mountain regions, on the whole lie conformably one on another and preserve to a large extent their original horizontal positions, a state of things well illustrated in Canada, especially in Ontario. The movements of the earth's crust must, therefore, have been fairly uniform and quite slow, both in sinking and in rising.

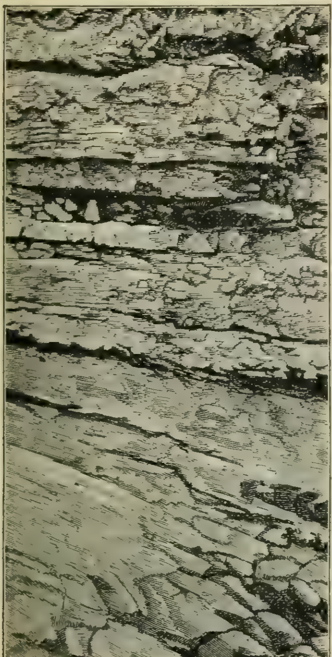

FIG. 17. Siluro-Cambrian strata, nearly horizontal, resting unconformably on gneiss. Quebec. (Geological Survey of Canada.)

But there were two great disturbances and uplifts in our North America. One gave the mountains running from the Hudson River up into Gaspe, New Brunswick, Nova

by its Indian name, the *Kwahaug* (the first $a = a$ in "call"), in New York the "hard clam." It belonged undoubtedly to shallow water, or even to a bottom left bare by the tide. When the creature died, its soft parts and then its shell decayed, their place being taken by material from its surrounding bed, and thus a *cast* alone remains, not the shell itself.

† That is, an animal that has a crust or soft shelly covering, like a lobster. The *trilobite* has three "lobes" or divisions of its shell.

Scotia and Newfoundland. Here the old Archæan ridges are mingled with Cambrian and Lower Silurian ones; the latter are so thick—20,000 feet—that the floor of the sea where they were formed—a very shallow sea—must have been slowly sinking through long ages, while the ever accumulating sediment kept the sea about at the same depth, till finally an opposite movement set in and the strata that were thus formed on the sinking bottom of the Silurian seas, were forced out of the water and high in the air in great folds, crushing, dislocating, contorting the strata, while the great heat attending it gave crystalline rocks in abundance, the many and varied marbles making this region particularly famous.

The other great disturbance brought the Palæozoïc period to a close—it was the great earth movement that,

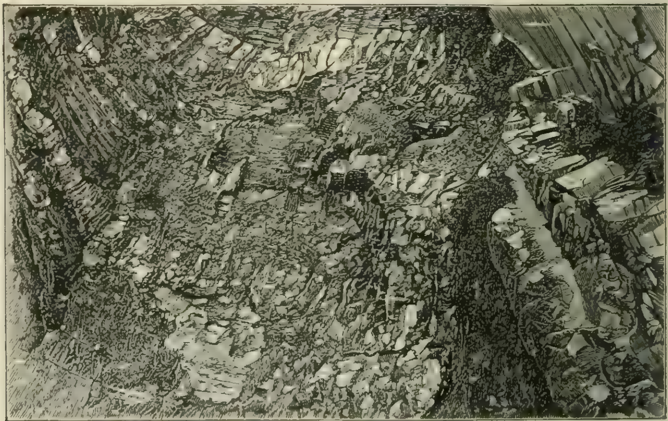

FIG. 18. Contorted Cambrian strata; a cutting in a street, St. John, N.B.

lifting Cambrian, Silurian, Devonian and Carboniferous strata alike, resulted in the upheaval of the Appalachian mountains, a set of ranges that extend for a thousand miles to the south, from the Hudson to Alabama. Here, too, though there was much alternate rising and sinking of strata, there must have been on the whole, a great subsidence, beginning away back in early Silurian times, for Palæozoïc rocks are here over six miles thick. What made the bottom

of the inshore sea thus sink to so great a depth and then heave itself aloft again, it is hard to say. But whatever caused the sinking, the rise, many geologists are assured, was caused by the enormous pressure of the vast beds of sediment gathered farther off-shore—their weight, in these deeper waters of the ocean, pushing sidewise against the sloping beds farther in-shore, forced them to rise.

But the rest of the world was also the scene of disturbances. These were particularly violent in Western Europe, though at a little earlier date than in America, and with the usual results of distorted strata and elevation into mountains.

LIFE IN PALAEOZOÏC TIMES.

Naturally during the inconceivably long Palæozoïc period life made great advances. Beginning with lowly coralline creatures, sea-worms and sea-weeds, it passed upwards through ever varying and higher forms, till the rocks of the closing ages show remains of the highest kind of land animals, the *vertebrates*,* though in the lowest, or reptilian, form, and of such land vegetation as tree-ferns, club-mosses and horse-tails—but all of gigantic size—and such cone-bearing trees as spruces and firs.

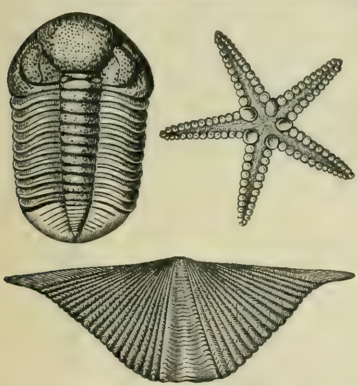

FIG. 19. Palæozoïc fossils: star-fish, Upper Silurian; trilobite and spirifer, Devonian.

The early ages of the period abounded in marine life. The Cambrian rocks show the remains of sponges, of shell fish, of sea worms, and of crustaceans. Here we find that peculiar crustacean, the *trilobite*, met with in various forms all through the palæozoïc rocks but nowhere else, showing endless abundance in the Lower Silurian strata, and disappearing with the Permian. There was no land-life, no fish, no other vertebrate.

*That is, those having a backbone.

But the Lower Silurian supplies the first land-plant, a kind of fern, and the first land-animal, an insect like the cockroaches. In the seas now appeared the fishes—a vertebrate, but only the scales have as yet been found; while jelly-fish and their kindred, the *echinoderms* (star-fishes, sea eggs and the crinoids or stone-lilies), besides many and varied kinds of shell-fish and corals, and the ever present *trilobite*, were swarming in the waters. *Invertebrates* characterized the seas of this and the Devonian period.

In the Upper Silurian the life both on the land and in the sea differed little from that of the Lower Silurian; but in the Devonian the ferns, horse-tails and club-mosses, which had merely appeared before, became trees and grew in thick jungles in the swampy grounds, while on drier reaches grew the *conifers*, the cone-bearing trees, such as spruce, fir and others of the pine family. New varieties of shell-fish came in together with the earliest of the lobsters and crabs. The fishes increased greatly in variety, size and numbers, showing what they would come to be in future ages. There were great sharks, some as large as now, but only their teeth and spines are found, for sharks have no bony skeleton; still others existed, and of a formidable character. This, the Upper Silurian, was the great AGE OF FISHES.

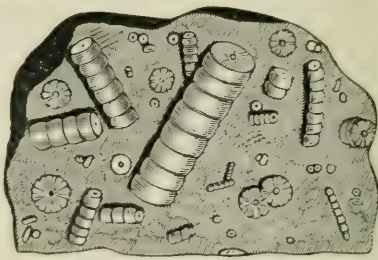

Fig. 20. Encrinite (*stone lily*), and fragments of stem in crinoidal limestone.

MINERAL PRODUCTS.

To the rocks of the Devonian period we owe our coal-oil and natural gas, though the particular beds from which they come are not the same in the United States as in Canada. Some scientific men think that the oil is really an animal product for the most part, coming from the decayed bodies of the swarming life in these early seas, increased, perhaps, from the abundant vegetation of

the Devonian swamps and upland; others think it came from a peculiar shale rock as the result of being exposed to heat or great pressure. The gas is a "by-product" of the oil.

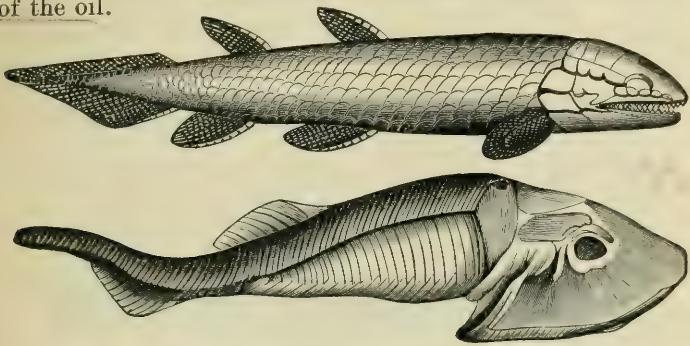

FIG. 21. Two Devonian fishes,–Osteolepis (bony-scaled), and Cephalaspis (shield-headed).

CARBONIFEROUS AGE. The change from the Devonian to the Carboniferous was very quiet and gradual, for almost everywhere the rocks of the latter lie conformably on those of the former. Nor was the upheaval very great, for the fossils of the preceding rocks show shallow water, and the great and strongly marked feature of the Carboniferous was low, swampy, almost steaming ground with a dense forest or jungle growth. This last feature, with its resulting coal-beds, gives the Age its name. We have none of these rocks in Ontario nor in any other part of Canada except the Maritime Provinces, Nova Scotia especially. But they exist in Europe widely, though the "Coal Measures" are almost limited to the western part, Great Britain having nearly as much as all the other countries together.

The geological map (Plate I.) shows the position in North America of these most important rocks.

COAL. It is well known that coal consists of vegetable matter. In the coal beds erect trunks of trees are found with the lower part changed to coal, while the upper part above the coal is stone; roots extend from the bottom of the trunk—and even where there is no tree trunk—down into the shale, conglomerate or sandstone that usually

underlies the coal. Plant remains of various kinds—leaves, branches, fruit,—are met with in the coal, and in the rocks above the coal-seams; peat-bogs at the present day in their lower parts seem to be turning into coal; and the microscope shows that coal, even the hardest anthracite, has the structure of vegetable tissue or wood.

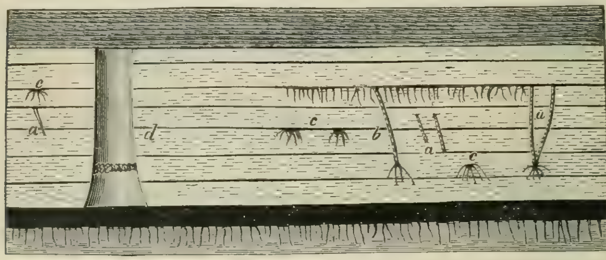

FIG. 22. Seam of coal with upright stem of fossil tree rising from it through beds of sandstone, etc., the beds below and above the coal showing fossil rootlets. Nova Scotia. (From Dana.)

But the coal beds are not all in one seam; in some places in England the coal-bearing strata show nearly a hundred seams of varying thickness, separated by beds of shale, sandstone or conglomerate. It must have been, therefore, that the low, swampy regions and shallow lakes, after accumulating masses of decayed vegetable matter, as our swamps and peat-bogs are doing now, sank below the water, and having received deposits of mud, sand, etc., rose again, and in the course of time bore another growth and accumulated another mass of vegetable matter, only to sink again and receive another deposit of mud or sand. And thus the process went on, the same conditions recurring again and again, till at last after the sea had covered all once more, a succeeding convulsion threw the strata high in air where they now rest, and where the great breaks, or faults, occasioned by the crushing upward movement, or the wasting away of the rocks through long ages of exposure to wind and storm, have brought to sight at the surface of the ground those priceless stores laid up for us in that distant age.

The form in which coal appears is not due alone to the decay of vegetable tissue and its burial beneath repeated

loads of sand or other material. Heat is needful in addition to pressure. The imperfect coal which we call lignite, so common in Western Canada, belongs to the later geological periods and has not been buried deeply, still less subjected to heat. Where the real coal is found, the rocks all show the action of heat, and the greater the heat the greater the hardness of the coal. The anthracite coal is the product of much greater heat than is the bituminous coal; and still greater heat was needed to form the intensely hard coal of Rhode Island.

LIFE IN THE CARBONIFEROUS. The vegetation of the Carboniferous was extraordinarily luxuriant as the coal beds show; but it was very like that of the preceding ages, consisting, along with conifers, mainly

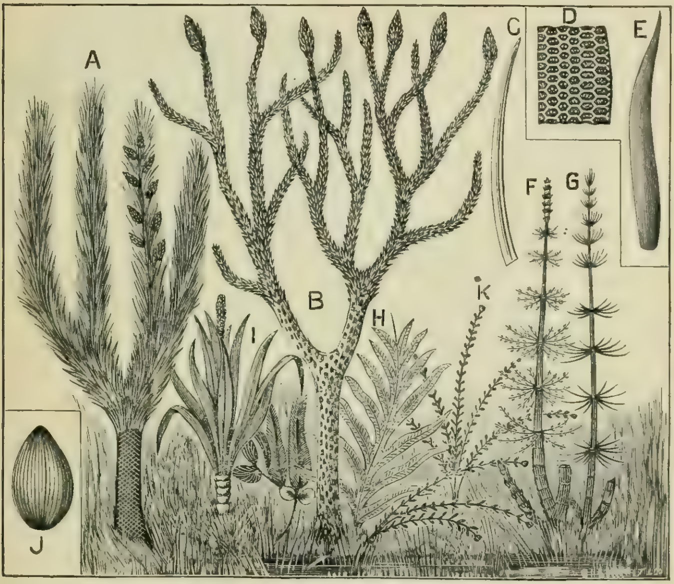

FIG. 23. Carboniferous Vegetation, restored. A and B are two kinds of Lycopods, *club mosses*, stems showing leaf-scars: C, the leaf of B, one-fourth natural size; D, part of stem, greatly reduced, of a kind of Cycad, resembling A, showing leaf-scars; E, leaf of same, one-fifth natural size:—this tree, called *Sigillaria*, had the most to do in forming coal: F, G, Equisetums (*horse-tails*); I, thought to be a Cycad, leaves very abundant in coal; H, K, ferns, another being figured in part, between I and B; K resembles a maiden-hair fern; J, a nut.

of flowerless plants,—ferns, horse-tails, a gigantic rush and a huge kind of ground-pine, or club-moss, whose curiously marked stems are so common in carboniferous shales.

Shell-fish of many kinds abounded with corals, echinoderms and the ever present trilobites. On land, insects greatly multiplied, including spiders and scorpions. The vertebrates became numerous and important; in the sea, higher types of fishes appeared, and on land, reptiles—a great advance in terrestrial life.

CLIMATE OF THE CARBONIFEROUS. The vegetation of the period could exist only in warm, moist climates, for our modern tree ferns are met with only in such climates, notably in Australia; the remains of tree-ferns are found in Carboniferous rocks the world over, in Spitzbergen and Texas alike; corals live only in warm seas, and fossil corals are found everywhere. So it is quite certain that a warm, moist climate,—the atmosphere being laden with carbon dioxide, many think,—existed in the tropical and the polar regions alike.

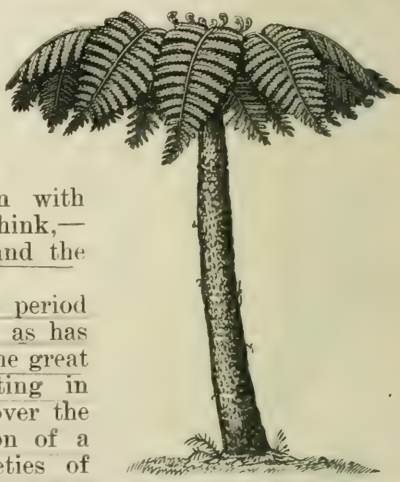

Fig. 24. A modern tree-fern, the stem showing where fronds have been.

The great Palæozoïc period was brought to a close, as has already been said, by some great earth movement, resulting in mountain making all over the world, and the extinction of a great number of varieties of life, animal and vegetable.

MESOZOÏC PERIOD. The period of "Middle Life" follows—hardly more than a quarter as long as the Palæozoïc—and at its close North America was nearly complete, the south-eastern and the Gulf of Mexico regions alone having to receive some narrow additions in the next period. The strata of the first two divisions, very commonly red or brown sandstone, occur in America only as long, narrow strips, as if they

had been laid down in long, narrow inlets of the sea, and in Europe as beds, more or less separated from one another, as if the whole continent was then a collection of islands. And they often contain great beds of salt, as in England, or of gypsum, as in Nova Scotia, which seems to show that the bodies of water in which these were formed were almost cut off from the ocean and had become very salt through evaporation, just as is the case to-day with very many of the bays around the Caspian Sea.

These strata form all of Prince Edward Island and the long, narrow valley in Nova Scotia called the Cornwallis

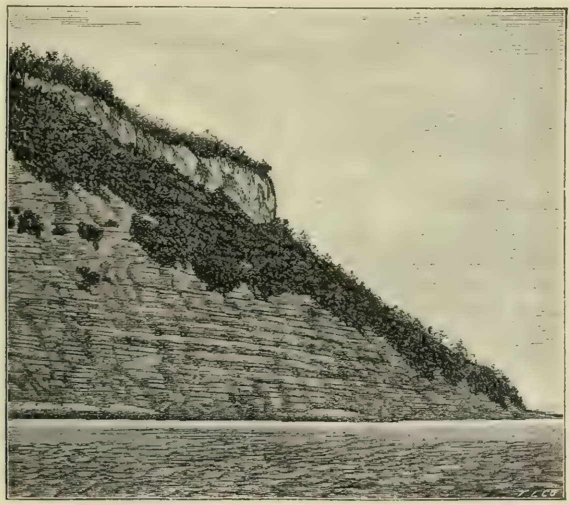

FIG. 25 Cape Blomidon, N. E. extremity of North Mountain, Minas Basin, Nova Scotia. Basaltic trap piercing through Triassic Red Sandstone.

and Annapolis valley, extending between the North and South Mountains from Minas Basin to St. Mary's Bay, both of which are sunken portions of the same valley. Nowhere else in Canada, excepting a few limited areas near the Pacific coast, are these strata found. But the strata of the other division of this period, the Cretaceous, form all the central portion of the western part, including the Rocky Mountains, not only of Canada but of the United States

and on into Mexico. And these strata contain all the coal-fields of the West, some of which, in British Columbia, from the great heat and pressure accompanying the upheaval of the mountains, are of anthracite.

A very peculiar feature of the first two divisions is that the strata, wherever they occur, are almost always associated with long ridges of *trap*, an igneous rock, as if great fissures had suddenly been formed by the strata giving way, and volcanic ashes and lava had poured out, piling themselves up steeply, often like great columns, on one side, and sloping off gently for miles, sometimes, on the other. Such is the North Mountain, referred to above, a ridge four or five hundred feet high and over a hundred miles long; and such is the origin of the famous "palisades" on the Hudson River. But there were great outflows of lava from fissures in the Cretaceous as well, in the Rocky Mountain region, and notably in India.

To the Mesozoïc times we owe the great western mountain mass of North America: its western chains belong to the early divisions, the Rocky Mountains, except some Laurentian islands, to the last one. With the rise of these latter came the rise of all the part to the east not yet out of water, and then all that remained of what was once ocean here was a long chain of great lakes that speedily became fresh. Thus closed the Mesozoïc Period.

LIFE IN MESOZOÏC TIMES.

In Plant Life, along with the spruces, pines and cedars of the last divisions of the Palæozoïc, oaks, beeches, poplars and palms came in toward the close of the period, but the characteristic tree was what is called a *cycad*, like a palm in appearance but not really such, of which the only ones that now remain are what we call "*sago palms*."

FIG. 26. A modern cycad.

But the characteristic Animal Life was most extraordinary; it was the AGE OF REPTILES. Some of the reptiles were so large as to be over ninety feet in length, the Deinosaurs (*dreadful lizards*) being the largest. Some lived on the dry land; others, the largest, in swamps and along muddy shores; some lived on herbage, some on flesh; some walked on all four legs, others only on the two hind ones—monsters whose fossil skeletons are found in many places in the Old and the New World but are particularly abundant in Colorado and Wyoming, while their tracks are very common in the red sandstone of the Connecticut Valley.

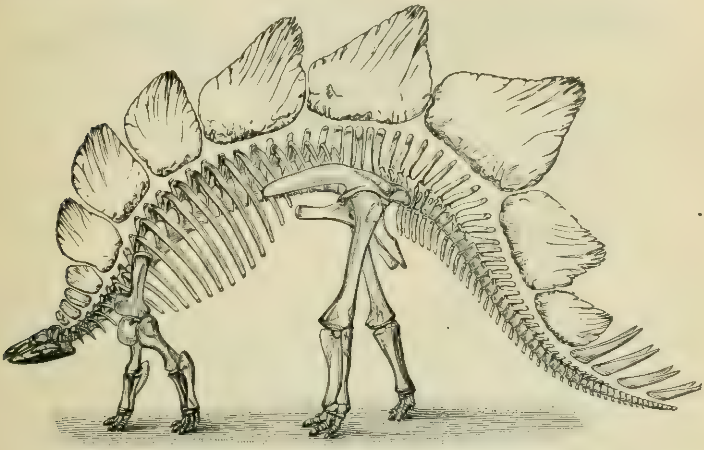

FIG. 27. A Deinosaur; the back protected by bony plates; length of living animal about forty feet. (After Dana).

The sea had its monsters too, reptilian as well,—the Ichthyosaur (*fish lizard*), forty feet long, with long, crocodile head and huge jaws set full of great teeth, monstrous eyes, short neck, bulky body, and tail and fins like a fish; the Plesiosaur with long snake-like neck and big body. In the air flew the Pterosaur (*winged lizard*), a bat-like reptile with membranous wings and great jaws. The birds, for birds are now first met with, had teeth, and long reptilian tails but covered with feathers, and claws on their wings as

well as on their feet; while the mammals, the highest class of animals, appearing towards the close of this period for the first time in the world's history, but in their lowest forms, had reptilian features too. But with the close of the period these all passed away.

The climate of Mesozoïc times was still warm, for fossil tropical plants are found in the strata far up in the high latitudes, though we must suppose that the great increase of land and the elevation of the great western mountain ranges had a very marked effect on currents of water and of air and therefore on the climate also.

FIG. 28. A Pterosaur. (After Dana.)

CAINOZOÏC (TERTIARY) PERIOD.

The period of the "New Life" brings the story of the earth as written in the rocks, down to our own day. In the earlier divisions of the period North America received its latest deposits of sediment along the south-eastern coast from New Jersey to Mexico, while the chain of great lakes, left from the Mesozoïc times in the eastern part of the plateau region and its approaches, in Canada as well as in the United States, accumulated sediment from the new land round about them, till an elevation took place in east and west, forming a low, flat, verdant border, along with Florida, in the east, and in the west either wholly destroying the lakes whose sites are now too often only wide stretches of scorched, barren plains covered with alkali, or shrinking them up to far smaller dimensions, such as the Great Salt Lake.

In Canada the Tertiary strata are found only in Alberta and Assiniboia,—the region of lignite, where neither heat

nor pressure was sufficient to turn the beds of peat into true coal,—and in British Columbia around the shores of the Gulf of Georgia. But they are abundant all over the other parts of the world. All over the world, too, they have been subject to great upheavals; they are high in the Rocky Mountains and in the Alps, while in the Himalayas they rise 20,000 feet in air; one vast area extending through Central Europe to India and including Egypt, sank beneath the sea, and having received its new deposit and characteristic marine life, rose again, and we now find similar fossils all over that region. Great outpourings of

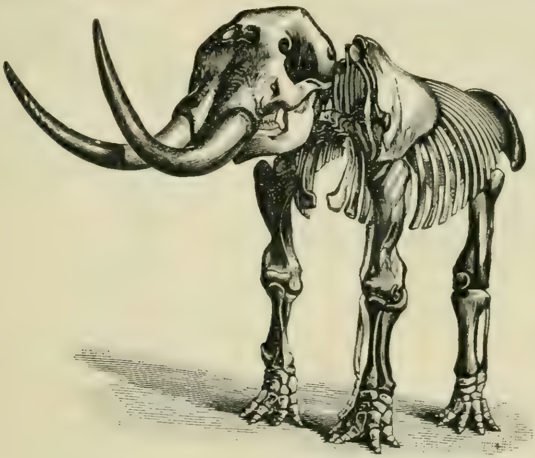

FIG. 29. A Mastodon, a mammal; skeletons have been found over 17 feet long and 11 feet high.

lava also took place, notably in the Rocky Mountains, which filled valleys, destroyed lakes, and blocked up rivers, compelling them to change their courses and cut new channels. But on the other hand many men of science think that a great area of land connecting Madagascar with India and the intervening islands and even with Australia, sank permanently during this age, for nothing but a former connection can account for the great similarity of animal life in these regions.

LIFE IN CAINOZOÏC TIMES. Life was now becoming quite modern; the forests had most, if not all, of the modern trees — palms, maples, hickories, etc., and the seas the salmon and the whale. But the feature of the age is the great development in animal life of the mammals—animals that suckle their young—beginning with the humblest class, the marsupials or pouched animals, such as the kangaroo and opossum, and passing upward into the very highest type of brute creatures, some, as the mammoth, being gigantic in size. It is the AGE OF MAMMALS. Insect life, too, became for the first time abundant, and thousands of species have been found embedded in amber, the fossil gum of cone-bearing trees, met with so plentifully on the shores of the Baltic Sea.

FIG. 30. Fossil skull of Deinotherium. Like the mastodon and, later, the elephant, it had a trunk; tusks on lower jaw.

The climate throughout the first three ages of this period must have been still generally warm, for palms grew in Britain, while oaks and beeches and magnolias—the last now found only in warm climates—were abundant in Greenland and other arctic regions.

THE GLACIAL EPOCH (PLEISTOCENE). But a great change in climate was at hand, with its result, in the *Great Ice Age*. Spread over the northern part of the continent, except the extreme north, and resting on all other rock formations wherever found, is a loose mass of clay, sand, or gravel, mixed with boulders sometimes thousands of tons in weight.* Usually all are of the same material as the underlying rock, but the boulders are frequently of a material found only hundreds of miles away, and are often rubbed and rounded, and sometimes scratched and grooved. The rocks that underlie this "Drift," as it is usually called, are found, where exposed to view, to be worn and

*Beginning at Cape Cod in the east the southern boundary of the Drift runs S.W. into New Jersey, thence N.W. through Pennsylvania to the Ohio River, whose general course it follows S.W. to the Mississippi where it turns N.W. following up the Missouri to the Mountains.

grooved also, and where of a hard nature, scratched and polished as well, and rounded if at all rising above the surrounding level. (See Frontispiece).

Then at varying distances from its southern limit this drift, besides being spread out over the country, runs in several irregular lines of long, low hills or mounds from Cape Cod, where it passes beneath the sea, almost to the mountains in the west.

FIG. 31. Cutting in Glacial Drift. New Brunswick.

ORIGIN OF THE DRIFT. The rocks over which glaciers have passed, are seen to be polished and grooved and scored, the work of the stones, gravel, etc., buried in and beneath the ice and crushed against the rock by the enormous weight of the glacier as it moves down the valley; then at the end of the glacier, where the ice melts, the boulders, gravel, etc., buried in the mass or carried on its surface, are piled up in huge heaps often hundreds of feet high; but if from any cause the glacier should retreat its load is spread out over the ground. From this last circumstance it is known that the Swiss glaciers once extended very many miles west of where they now end. Then, too, Greenland, except a small portion, is covered with an ice cap of great but unknown thickness, only a few mountain peaks near the east coast protruding a score or so of feet above the universal ice. This ice cap is not at rest; it is moving sea-ward, for from its edges that are pushed out into the sea, break off the icebergs that are so numerous and so dangerous in the north-western Atlantic.

These facts undoubtedly prove that the drift-strewn area in North America,—and in the north-western part of

Europe, which has its drift area as well,—was once covered by a huge glacier or cap of ice, and that all the scratchings and groovings, and all the polished and rounded forms of the bed-rock are due to the flowing of the ice outward from its gathering ground, which from carefully tracing backward the boulders to the sources whence they came, and noticing the general direction of the scratches, or *striæ*, on the rocks, is seen to have been the Laurentian area around Hudson Bay.*

THE GLACIER. We must, then, imagine this glacier gathering century after century in the Laurentian ground, which probably, though not necessarily, was much higher than at present, advancing slowly upon the country, sliding over or pushing before it the covering of the rocks of other ages, tearing up huge fragments and grinding them into mud upon the rock beneath which thus became scored and grooved, or carrying them forward to be dropped hundreds of miles from their native bed; rounding off hills of harder rock here and scooping out wide hollows in the softer rock there; overtopping the mountains of the Atlantic border and rounding them into great white cones except where, as with Mt. Washington, over 6,000 feet high, their rugged summits rose above the enveloping ice; filling and, as it passed onward, deepening and widening the mountain valleys till, on the Atlantic coast, southward to Long Island, it pushed out into the sea, broke up and floated away in icebergs; while inland to the west it at length, after how long a time we know not, came to where the warmer temperature melted the ice as fast as it came forward,—and the great ice-sheet stopped.

FIG. 32. Bed-rock polished and striated by ice. Baie Verte, N.B.

Then, during the long pause, there grew up at the base of its front across the whole country, an irregular line of mounds of mingled clay and sand and gravel with boulders of all sizes and shapes,—smooth and rough, scratched and polished,—its *moraine*, the load it had borne along with it from regions far and near. Again a change came over the climate. It grew warmer. The

*In the eastern part of the glaciated area the general direction of the striæ is S.E., in the southern part S., in the western S.W.

glacier slowly got thinner and its front began to break up and recede, for the ice that still advanced from behind, could no longer make up for the waste through melting; and now as it retreated it spread out its load of loose material over the whole country, sometimes, especially in valleys, to a great depth.

But this was not the end; the ice had only retreated, perhaps as far as the old gathering ground; if it had been the end the glacier would have left only one long irregular line of mounds, where it paused; but there are several of these and often at considerable distances apart. And so we must think of the cold again becoming greater, and the snow increasing in depth century after century on the Laurentian gathering ground, till its accumulated weight forced the ice to flow outward once more,—for ice has all the movements of water,—and again an ice-cap was over the land.

If we can trust to the number of lines or partial lines of moraines that exist, there must have been several of these advances and retreats each leaving its long line of rubbish where it finally stopped. So we see the Swiss glaciers after retreating for years advancing again and again retreating.

Some geologists, however, believe that there were more than one glacial epoch; that the first ice-cap wholly disappeared and that after a long interval, during which the climate was warm, even tropical, the cold returned and a new glacier was formed which advanced almost as far as the first, and its pause there caused a new moraine almost as long as the other. The discoveries made at and near Toronto furnish strong proof of the existence of this "Interglacial Epoch," for between underlying and overlying beds of glacial material containing remains of plants and animals belonging to a cool or cold climate, other and thick beds are met with that yield trunks and leaves of trees, of a kind now found only in the southern United States, and shells of a clam—the Unio—now living only in the lower Mississippi.

CAUSES OF THE GLACIAL EPOCH. Several theories have been put forth to account for this Age of Ice. The one most generally received supposes that there was a great and general upheaval of the land in the northern part of the northern hemisphere during the latter half of Tertiary* times, which, by shutting off from the Arctic seas the warm oceanic currents, and by forcing to the higher regions of the air the warm moisture-laden winds from the south, gradually brought about a state of things that could not fail to produce great cold and a heavy snowfall. Another theory says that at the time of the Glacial Epoch the earth in its yearly revolution round the sun went to its greatest distance from the sun, and that when it was at this greatest distance,—in *aphelion*,—the northern hemi-

*This part of the Tertiary is called by different geologists Post Tertiary, Quaternary, and Pleiocene. Plate II.

sphere was turned away from the sun and so had its winter there, which was longer than it is at present by forty-four days, and therefore the snow and ice had time to gather in such quantities that the short summers, though very hot, could not melt all away again. And so the accumulation continued century after century till the whole land was buried, and continued in this state for thousands of years till the earth's orbit was shortened again, when shorter and less severe winters returned.

EFFECTS OF THE GLACIER. But the ice at length was gone, all but the patches that still cling to the hollows high up among our western mountains, which

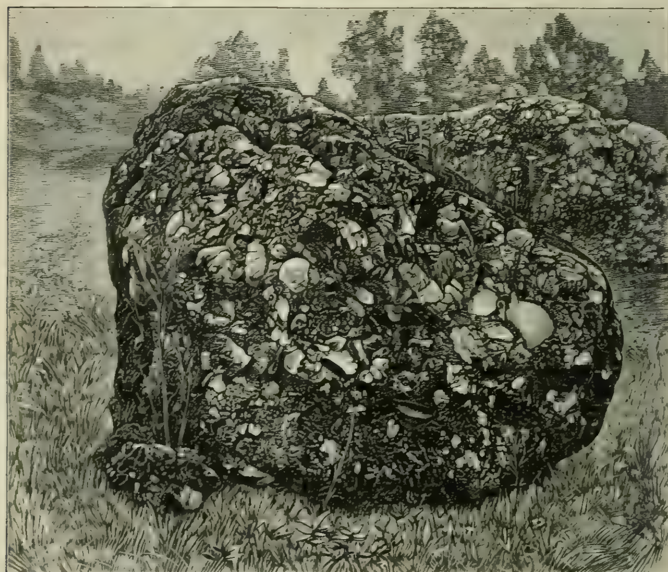

FIG. 33. Glacial boulder, conglomerate, probably from conglomerate bed-rock in neighborhood. St. John, N.B.

had formed a glacier of their own that flowed away eastward till at the head-waters of the Saskatchewan it met the Laurentian ice-flood and the two became one.

The retreating ice must have left the country very much changed from what it once had been. The long exposure to the terrible mill

of the glacier must have ground down the country to a very great extent in order to furnish the drift that we see spread out everywhere. In some places, doubtless old valleys, it is known to be over a thousand feet thick; but in the Laurentian land, the gathering ground, it was thin and collected in hollows, while the hills stood out rounded and bare, as they do to-day where the rains have washed away the soil since the trees were cut down, or where fire has burnt up trees and soil alike. Loose boulders were sown broadcast over the country, in plain and valley and on mountain, even to the top, almost, of Mt. Washington, a proof of how thick was the ice in that region.

Innumerable little lakes,—and nowhere are they so abundant as in Canada,—filled the hollows scooped out in the rock or lying between hills of drift; larger ones occupied valleys whose outlets were dammed up by the same material, while here and there little circular ponds with

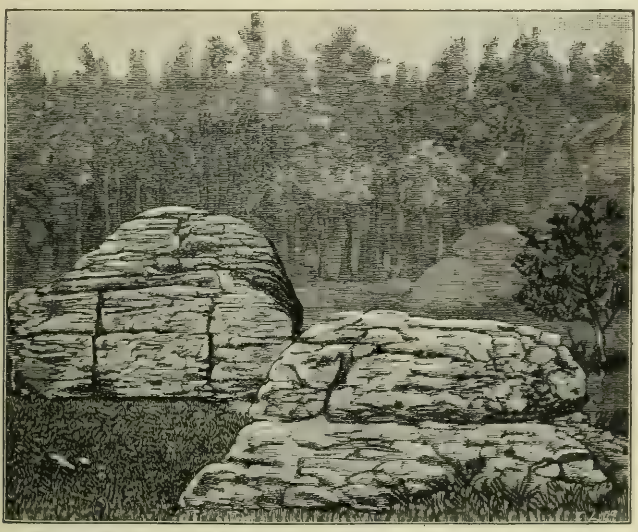

FIG. 34. Remnants of water-worn sandstone cliffs on the old beach of Lake Agassiz, Manitoba. (Geological Survey of Canada.)

drift piled high all around them, "kettle holes," marked the spot where perished huge fragments of ice that had broken away from the glacier and were left to melt away alone. See Frontispiece.

River-valleys were filled up so that the water, which was more abundant than before by reason of the melting ice, had either to seek new channels as did the St. John through the gorge below the Grand Falls, and the Mississippi that now flows from a glacial lake, or again to cut out the old channels, leaving, as their beds got lower and lower, wide terraces of stratified drift along their banks. (See page 142).

According to many geologists other and very remarkable occurrences attended the retreat of the ice. In Manitoba and extending down into Minnesota the shores of an old lake of great size can be readily traced on all sides, while the country between has all the appearance of having been long under water. Through this flows the Red River, whose lower course was, perhaps for thousands of years, blocked up by the glacier, while the accumulated water having no outlet northward spread out over the whole country along the ice-front, forming a great lake, *Lake Agassiz*, which discharged its overflowing water into the Mississippi through the Minnesota. The lake disappeared when the ice had at last left Nelson River free, and there remained the fine rich soil of the Red River basin in Manitoba, which gives its magnificent wheat crops to the world to-day.

Others think, however, that Lake Agassiz was a lake lying at the base of the high Laurentian land to the north and having its natural outlet as stated above; but that when the Laurentian land subsided the northern rim of the lake sank lower than the rim at the south, and so the lake drained off through the Nelson, the Red River changing its course.

So, too, the existence of similar beaches shows, doubtless from the same cause, viz., their ice-barrier, that the four upper Great Lakes once formed one, *Lake Warren*, having its outlet into the Mississippi past Chicago, where a recently dug canal has opened the old channel. The further retreat of the ice opened a lower level across the Niagara peninsula, and then the Niagara River began its career while the passage at Chicago was abandoned. But the ice still blocked the St. Lawrence; and now there was another great lake comprising Lake Ontario and a great deal of what is now land on all sides of the lake, the outlet being past Rome, New York State, into the Mohawk and thence into the Hudson. The old beach, very distinctly traceable in most places, comes down to the present Lake at Scarboro Heights, and includes the Davenport Ridge just north of Toronto. This is *Lake Iroquois* and the *Iroquois Beach.* When the ice left the St. Lawrence the lake drained off through

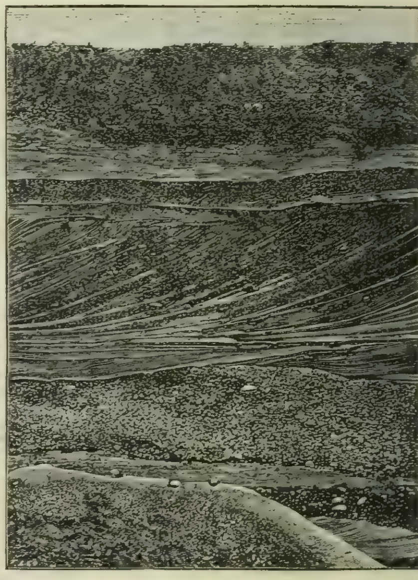

FIG. 35. Gravel pit, Iroquois Beach, at East York, showing cross-bedding in beach-sand and gravel.

its lower opening, the surface fell, the passage at Rome was no longer of use, and an area of level land, often quite wide, was left beneath the cliffs that formed in many places the old shores, an area upon which now stand many cities and towns,—Toronto, Hamilton, St. Catharines, Oakville, and many others east, west and south,—or which yields from its fertile soil rich crops of grain and fruit.*

LIFE DURING THE PLEISTOCENE. We have seen that during the earlier parts of the Cainozoic Period the life of northern latitudes was largely such as belongs to a much warmer climate than now prevails in the same regions; but the cold of the Glacial Epoch not only destroyed all life where the ice was, but greatly changed the character of the life farther south. For the plant-life being that of a warm climate, either perished from the cold or slowly drew back to the south, while Arctic vegetation or that of a cold-temperate climate, took its place. So when warmer times again came in, only the hardier of the

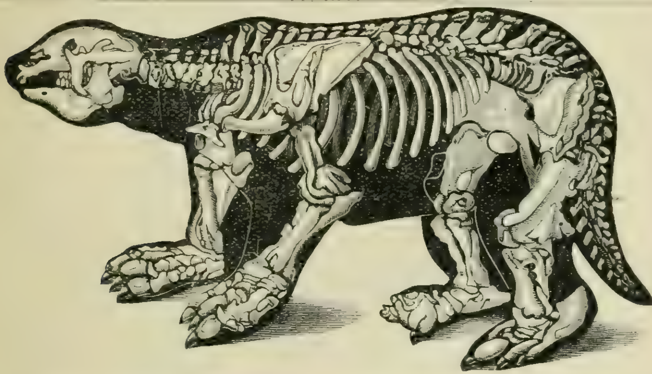

FIG. 36. Fossil skeleton of the Megatherium, a South American sloth; over 20 feet long.

surviving plants slowly came back, the Arctic ones retreating to the north or to mountain-tops where we now find them.

The remains of animals,—real bone and real shell, not petrified or only casts,—are no longer found embedded in the rocks, but buried in bogs, in the bottoms of dried up lakes and ponds, along rivers and around lakes and seas,

*Of course, if one of these lakes was an interglacial lake, its existence was due to an elevation of the land eastward, not to an ice-barrier, for no such barrier could exist there with a tropical climate at Toronto.

and in caves where beasts of prey used to drag their victims to devour them. The animals were still, many of them, of a very large type, extinct in our day,—the *Recent Era* of geologists,—or existing only in warmer countries. This last fact seems to show that we have now a cooler climate than that following the glacial times,—a climate not suited to the elephant, lion, rhinoceros, hippopotamus, the remains of all of which are found in caves in England. We know the bones of the mammoth are found in Ontario and even in the Yukon region, while the perfect animal, hair, flesh and all has been found in the frozen gravel and ice of northern Siberia, where it could not now exist. South America had its huge sloths, heavy in body and dull in movement, and Australia its great marsupials, the characteristic of that continent still.

CHANGES SINCE THE ICE-AGE. Since the ice-age there must have been in the northern part of the Northern Hemisphere a considerable subsidence of the land, —a state of things called the Champlain Period by American geologists,—followed by a partial rise again. For all along the Atlantic shore, in Europe as well as in America, and along the Gulf of St. Lawrence, occur old sea-beaches lying far above the present ones, and containing the shells of the very same species of marine animals as now inhabit the neighboring waters. The beaches are three hundred and seventy-five feet above the St. Lawrence at the Saguenay, five hundred and twenty feet at Montreal, and six hundred near Lake Ontario. From this we can see that the St. Lawrence River was then a very deep gulf with Lake Champlain as an arm of it.

Furthermore, the beaches of the old Lake Iroquois, and of Lake Warren as well, are seldom found on a level with themselves, but vary very greatly in height above the surface of the present lakes,—all, however, showing a higher position toward the north and east than toward the south and west. This fact seems to show that the ground is being gradually, but irregularly elevated to the north and east. If such continues, the result on the Great Lakes will be to send their waters once more into the Mississippi past Chicago and destroy Niagara.

One further great change may be mentioned. The

waters for over a hundred miles west of the British Islands and all to the east, are very shallow and the shores facing the continent are very similar in character; the animals and vegetation are the same as on the continent, and the remains of the Recent Period are the same. The British Islands of the present day are only the highest portions of a region whose low-lying plains have sunk beneath the sea in Pleistocene times. That Africa was in these times connected with southern Europe, and that a broad belt of

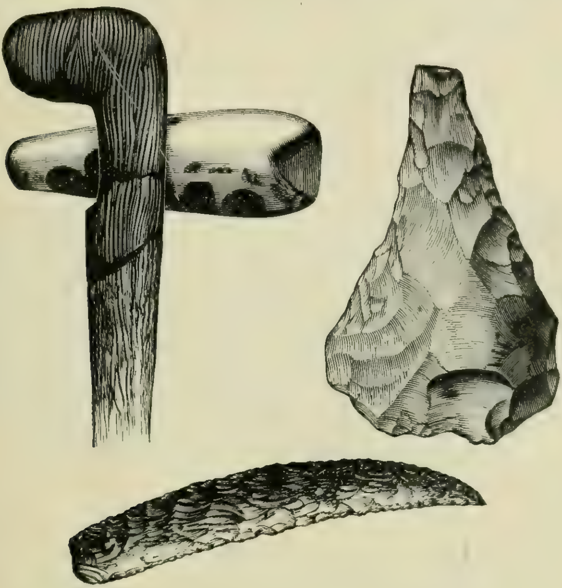

FIG. 37. Some implements of the "Stone Age."

land stretched across the Atlantic from Great Britain to Newfoundland and Greenland, have already been referred to

MAN. But the Pleistocene has a greater interest for us than has any other age or period in the earth's history, for immediately after the Glacial Epoch, or perhaps during it, MAN comes on the scene. His presence is made known by rudely shaped arrow heads, hatchets and other implements chipped from stone, found along with the remains of

animals in caves; traces of fire are met along with evidences of cooking and eating, in the shape of charred bones, often split and broken open; human bones and a few human skeletons have been found in such association as to show that they belonged to those early times; carvings in ivory of animals,—mammoth, reindeer, etc., have been also found. Some think that the old race of man was swept away by the same causes as destroyed so many species of animals after the Glacial Epoch, and that the carvings, and other evidences of advancement, belong to a newer race—a race such as the Indians of America when first discovered.

Such is the record of the earth's history as stamped upon the rocks,—upon its mountains and rivers and plains; it is a record whose leading statements are clear and dis-

FIG. 38. Drawing of a hairy Mammoth on a piece of tusk, found in Southern France. The artist must have seen the living animal.

tinct, about which there can be no doubt. Not all of the minuter features of the record have yet been read, perhaps some are missing—have been destroyed by catastrophies. But what we have read tells us how our earth came into being, how it gradually grew and grew through changes small and great as untold ages came and went; what plant life and animal life came into being, one slowly succeeding the other, and each age bringing forth new forms of a higher type than any that had preceded, though still retaining some of the lower, till at last MAN appears, the most highly endowed of all earth's inhabitants,—and it can be said that *the earth is finished*.

CHAPTER II.

CHANGES IN THE LAND SURFACE OF THE EARTH.

THE LAND MASSES.

EFFECT AND CAUSE. Were the earth really "finished," were there no changes going on now, we could not tell that the earth ever had changed; we might suppose that as things are now, so they always were; that the fossils and every remnant of olden life came into existence just as we find them to-day, as did also rocks and streams, hills and valleys and all else that we call nature,—for our knowledge of what took place in the past depends wholly upon our knowledge of what takes place in the present. We see around us certain effects being produced and along with them the causes at work producing them; we see our hill-sides being furrowed with little channels, and the little streams, the result of a rainstorm, doing it; and we see, too, that similar effects are everywhere produced by similar causes under similar conditions.

So in our study of the earth,—itself one great effect,—we see individual effects everywhere and we seek to know their causes. If the causes are quite clear we need not seek farther, but if the cause in any instance is not clear, then we are led to look about us till we find a like effect being produced by a cause at work, and then we infer that the unknown cause was the same as this known one. The drift, the surface material that we find spread out over all Canada and more, and the worn and scarred condition of the rocks beneath it, are effects without any cause that we can see; nothing existing here could now produce them; but in Switzerland the glaciers are seen to be spreading out just such material, and rubbing and scarring the rocks likewise; therefore it is inferred that glaciers too did these things in Canada although no glaciers exist except among the mountains of the west. This principle has been fully illustrated throughout the preceding chapter.

SLOWNESS OF NATURE'S WORK. Again, nature often seems to work so slowly, even imperceptibly, that little or no change is noticeable during one's life, however long. But we must remember that to our short-lived race a few years are of the greatest importance, while to nature, time, so to speak, is of no importance. Nature takes as long as she pleases to do her work. Yet slow as her movements are, when we look back no farther than through historical times, we are startled to see what changes have taken place. Ravenna, a sea-port in the days of Cæsar, is now three miles inland; boats that bore Canute and his Danes to the shores of "The Wash," have been dug from the fen many miles inland; and the cliff along whose face ran the famous Pass of Thermopylæ, and whose foot, in the days of Xerxes and Leonidas, was beaten by the waves of the Malic Gulf, now rises from a broad plain stretching far away to east and north,—the work of the Spercheios River.

Frightful, too, is the rapidity with which nature at times may work; Mount Krakatoa, a few years ago, was in an instant hurled into the sea or flashed into impalpable dust that filled the whole atmosphere and spread over the length and breadth of the earth. Still, however great these changes, whether brought about in an instant or through long centuries, we must say that nature works slowly and that these are but local effects, important to the neighborhood where they occur, but having no apparent result upon the region as a whole, still less upon a continent.

It is very clear, then, that if the work of nature is done so slowly; if a thousand or two thousand years or more, even with the addition of periods of terrible energy, are needed to produce only mere local changes, the time necessary to bring about an important change in the form and appearance of a whole continent, must be exceedingly great, in comparison with which all historical time is but as yesterday.

THE FUTURE. If, moreover, the present thus looks back into the past, it also looks forward into the future. The outflow of heat from the earth will still continue, and contraction and folding of the earth's crust into elevations and depressions will still go on; volcanoes will

still pour out lava, rain fall, rivers run, waves beat, and sediment be spread out over the bottom of sea and lake, while winds will still drive the cutting sand, and frost shatter, and heat bake and crack the rocks.

In the world of life, too, change will take place as it has taken place. Every farmer knows how one variety of potato or one kind of apple "runs out" and new ones take their place; how a new variety of strawberry is often found in some corner of the field, and "sports" in fruit and flower alike are always taking place. And what surprising results come from carefully selected seed and wise cultivation! What a pride the florist takes in producing, through cross-fertilization and propagation, those endless forms of beauty in the flowers he loves! In animal life, too, "running out" and "improvement" both occur, as the stock-farmer knows full well. Added to this is the melancholy fact that the Pacific Islander and the North American Indian are passing away along with the buffalo and the dodo. "The old order changeth yielding place to new."

What in some future "Period" the earth will be in form, in distribution of land and water, in climate, in its varied life, we cannot tell. Our knowledge of the present and our knowledge of the past in all their workings and causes, is far too slight for us to foresee what will be. Only, if everything on our earth is under the control of "the blind forces of nature," then the final "Period" will be utter and absolute desolation,—the forces will have ceased to act; the earth will be "finished:" "Death lies dead." But we believe that the world is not under such control.

THE EARTH-FOLD. Nature's work in the past has left by far the greater part of the dry land drawn together in the northern half of the earth,—not quite continuous everywhere, for Bering Strait and the North Atlantic separate it into two parts, called the Eastern and the Western Hemisphere. But the former of these pieces of water is only forty miles wide and two hundred feet deep; and though the latter seems a much more important break, being 800 miles wide (from Greenland to Scotland) and 2,500 feet deep, yet when we consider that the rest of the Atlantic ranges from 6,000 to nearly 20,000 feet in depth, we see that this body of water, too, is quite shallow.

Soundings have been made in the coast waters everywhere in the world and it has thus been found that the

bottom of these waters always slopes off gradually from the land, never rapidly, so much so that, especially on the Atlantic coast of the Americas and Europe, a depth of 600 feet of water is not reached for very many miles off shore. Off New York this depth is eighty miles out to sea; off Nova Scotia and Newfoundland, where the famous "Banks" lie, it is far greater than this; while off Denmark the bottom seems almost level, and stretches away for over a hundred miles outside of Ireland before it lies 600 feet below the surface of the water. Eastern Asia, too, has this same peculiarity of shallow water far out to sea. In other regions, however, notably on the west of the Americas, the width of the shallow water is not nearly so great.

Wherever the land comes down to the shore with a gentle slope, the coast waters are shallow far out to sea, but where they are steep or abrupt, the shallow water is much less in extent. After this depth of 600 feet is reached, the water rapidly deepens, often to the extent of many thousand feet within a few miles,—becomes oceanic in character, as is markedly the case south-west of England.

The great gaps that lie in the southward projections of the earth-fold—the Gulf of Mexico and Caribbean Sea, the Mediterranean, the Malay Archipelago,—are not separations though they all contain large areas of water of oceanic depths, 18,000 feet or more. One of these is in the centre of the Gulf of Mexico, another to the south of Hayti, and third midway between these two; but all along the eastern boundary chain of islands from Florida to Trinidad, and extending east from Yucatan and Central America almost to Cuba, are great areas where the depth of water does not exceed 2,000 feet. The Mediterranean is crossed by at least two ridges, one at the Strait of Gibraltar, and the other from Sicily, over which the water is about 1,000 feet deep, oceanic depths being elsewhere; while in the Malay Archipelago, though very deep water occurs immediately west of the Philippines especially, yet elsewhere the greater part of the sea is not over 300 feet deep. These gaps are either the result of an upheaval not great enough to lift the folds above water, or the result, as many geologists think, of upheaval followed by subsidence, as is almost certain to have been the case with the Mediterranean and the Malay Archipelago.

Thus the soundings show us that the dry land is but the highest part of the flattened top* of a huge irregular fold, or wrinkle, on the solid body of the earth,† with some gaps or breaks in it of small but varying depth and breadth, which the water fills.

But the extent of the dry land is far surpassed by the extent of the water, for, while there are about 148,000,000 square miles of the ~~latter~~, there are only about 55,000,000 square miles of ~~the former~~,—a little over a quarter as much. Then the average depth of the ocean is far greater than the average height of the land; for while the highest point of land, Mt. Everest, in the Himalayas, is 29,002 feet above the sea level, and the greatest known depth of the ocean, in the south-west Pacific, is 30,930 feet, the general height of the land above the sea is calculated to be only about 2,300 feet, but the general depth of the ocean about 12,000 feet. So that if all the elevations on the lithosphere were evened off till all the hollows were filled up to a common level, the water would lie somewhere near 9,000 feet deep over all.

THE CONTINENTS. The inequalities, or depressions, on the top of the earth-fold that let in the sea, mark off, as it were, the land surface of the world into divisions. The shape of ~~these~~ will, of course, depend upon the shape of the fold itself almost wholly, but everything else, the mountains, valleys and plains—will depend upon the forces at work within or without the folds, the forces that build up or destroy. These divisions, or continents,—the two Americas, Europe-Asia, Africa, Australia, while having their own peculiarities, have each, one or more of their most marked features alike.

We have seen (page 20) that in old Archæan times the continent of North America already existed in outline; the Archæan continent, itself triangular, was attended, on the east and west, by two long strings of Archæan islands that

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*When such an elevation on the land rises 2,000 feet above the level of the sea, and its strata, except in mountains, are horizontal, it is called a *Plateau*, and the same term is used in reference to similar submarine elevations of any height. *Continental Plateau* is sometimes used to designate the great earth-fold itself; while *Continental Shelf* is applied to the top of this plateau between the 600 feet line and the shore.

†The solid part of the earth is termed *Lithosphere* (stone sphere) and the water the *Hydrosphere* (water sphere), just as the air or vapory mass around all is termed the *Atmosphere* (dust, or vapor sphere).

stretched away southward converging toward, but not reaching, a point, and were thus triangular as well. These lines of islands have become since then the plateau and mountain regions of to-day,—that on the east, separated from the Archæan region by the gap of the St. Lawrence River and Gulf, being the lower and narrower, but dating back to different ages of the Palæozoïc; that on the west unbroken, being by far the greater, undoubtedly from belonging to the younger Tertiary days; while between them, partly the result of sediment from the older land, partly the result of the gradual uplift on both sides, is the great plain of almost horizontal strata stretching from the warm waters of the Gulf of Mexico to the ice-covered seas of the Arctic, rising from each so gently that at its greatest height, in the region of the lakes, it is only about 1,800 feet above the sea.

South America has the same simple structure:—The Archæan block in the north, but smaller than in North America; the gap in the east, followed by a plateau and mountain region; the unbroken gigantic mass of plateau and mountain in the west; the triangular shape, the eastern side being broken, as in North America, by the dying out of the high lands; and finally, the great plain, which has a far gentler rise backward from the sea and to the right and left than has the other great plain, and which sediment from the surrounding high ground has formed with but little aid apparently from uplifting.

Africa, triangular in shape like the Americas, has, like them too, its own peculiarities as well as its features in common:—A central elevated hollow plain, or basin, hemmed in on all sides by girdling plateaus, or rather a rim of rugged country rising nowhere to any great height above the basin, excepting in the east where are the two lofty peaks Kenia and Kilimanjaro, and the massive plateau of Abyssinia. Through this rim the great rivers Zambesi, Congo, and, to some extent, the Nile have cut their way to the sea by a series of falls and rapids often in deep gorges. Like the two Americas, also, Africa ends to the south in a mountainous plateau region; but to the north of the Soudan the central basin drops into a plain, the Sahara Desert, with some strips of plateau in the east-central

portion, but low-lying for the most part, some spots in the north-east being below the sea level. Like the Americas, too, it has a block of Archæan plateau in the north, but elsewhere the desert plain runs to the sea.

Europe-Asia, properly one continent, no natural division between them existing, seems markedly different from the others. Its great plain, the greatest in the world, is at the north, stretching from the Bay of Biscay to Bering Strait, while its great plateau region beginning with the Spanish Peninsula, where it rises almost abruptly from the Atlantic, extends along the southern border with but one break, at the Dardenelles and Bosporus, to eastern Asia, where it spreads out and occupies the whole country before it falls to the narrow eastern coast-plain and sea. In many places this great plateau, though somewhat rough, has no mountains at all or only low ones; but in other places ranges run along its flanks, part off to north or south in more or less abrupt angles, rise from its top or start up to immense heights from its edges as do the gigantic Himalayas, whose great Mt. Everest rises 29,002 feet in air,—but all markedly tending toward the general trend of the plateau.

Australia is not triangular, though the submarine extension of the continental plateau through Tasmania does taper off to a point; but it has its central plain—a depression surrounded on all sides by elevated ground, from which the rivers that run inland, where there are any, form shallow lakes or are lost in the marshes, for not one reaches the sea. On the south there are no mountains, only a swell of the land to the height of 500 or 700 feet; on the west some low ranges, never more than 3,700 feet high, run for several hundred miles parallel to the coast and back some distance from it; to the north are low rounded ridges that serve as a watershed; but to the east the country assumes a plateau character, with several mountain ranges, one peak being 7,000 feet high, among which the Murray and Darling River,—the only great river of Australia, finds its way to the sea at the south.

Thus in the midst of much diversity there is much in the grander features of the continents strikingly alike, giving rise to the thought that so much uniformity is the

result of the operation of one and the same cause. The differences between the Europe-Asia continent and the others may be more apparent than real, for its southern extensions—Italy, the Balkan Peninsula, Arabia, Hindustan, Farther India, are all in form similar to the continents themselves. Then, too, while the land of the world has its great mass in the north sending great extensions into the south, the water has its great mass in the south, sending its great extensions into the north in corresponding forms; and still further, the great bodies of land on one side of the earth are opposite to great bodies of water on the other:—"Land and water are antipodal."

THEORIES. Such facts have led to many theories to account for them. One theory * is that while the earth was still in its liquid state, and before the new-formed crust got thick and hard, two great fiery waves of the molten, or half-molten, mass followed the moon in her revolutions round the earth, just as two tidal waves of cold salt water are doing now, till at last becoming too thick and stiff to move farther they remained fixed as huge ridges on the earth's surface.

Another theory † says that a hollow ball with elastic sides will gradually flatten as the air is slowly drawn out of it till it has four faces, each a perfect triangle, one, say, forming the top and the other three the sides, their apex being the same point. Thus, there will be four corners and six edges. Such a figure is called a *tetrahedron*, and it gives the greatest amount of surface for the least amount of matter, while a ball gives the least surface for the most matter. Now, the earth, a ball, in becoming cooler became smaller; but the outside could not shrink more than the inside, as it would have to do in order to keep the ball shape, and so the surface grew larger and larger in proportion to the rest. A perfect tetrahedron would have been formed if the cooling process had not been interfered with. For the revolution of the earth on its axis tended strongly to keep it round, and the attraction of sun and moon disturbed it, as did the upheavals and subsidences of strata and the unequal cooling of the outside and inside.

But in spite of all these hindrances there is still somewhat of the tetrahedral shape:—The edges of the top triangle form the watershed that runs round the earth near the fiftieth parallel of north latitude; the four corners are the Archæan regions of Canada, of Norway (with Sweden and Finland), and of north-eastern Siberia, from which run southward the great land lines that end in the Antarctic Continent,—the fourth corner, while of the flat sides the Arctic Ocean occupies the top one, the Atlantic and Pacific, each one of the others, but the remaining one has only its southern part occupied by water—the Indian Ocean—its northern part, to the east of the Urals, though containing the Caspian Sea and Persian Gulf, having been elevated into a low-lying

* By G. H. Darwin.
† Lowthian Green:—See "Plan of the Earth" in *Geographical Journal*, vol. 13 (1899), by J. W. Gregory.

plain excepting where the mountains of west-central Asia cross it. The water occupies the flat sides because they are nearer the centre of the earth than are the edges or corners, and water naturally gathers on the lowest surfaces.

ISLANDS. Besides the great and connected land masses there are other and isolated portions of land rising above the surface of the sea everywhere, and varying in size from a mere resting place for sea-birds to such great regions as Borneo and New Guinea.

These islands (or "sea-lands") are of different origins:—

The Continental Islands rise from the shallow water near the outer edge of the continental plateau, and are like the continents in being formed of stratified and igneous rocks, in the general direction of their mountain chains, and in the character of their plant and animal life, though nearly all possess both plants and animals peculiar to themselves. Probably most were once connected with the continents that lie nearest them and were formed by the same earth-movement as they. Such islands are found stretching along the continents in great chains; they almost fill the gaps between North and South America, and between Asia and Australia, and run in a great line down the east coast of Asia, and along Western Europe, while Western America, except in the North and South Pacific, has none; nor has Eastern America, except Newfoundland; Africa has none either except Madagascar. This latter island and New Zealand rise from water from 3,000 to 6,000 feet deep; but both are formed in part of stratified rock, and the sea-floor from which they rise is a ridge with very deep water to the immediate east and west. The ridge extends, in the case of Madagascar, through the Comoro Islands to Africa, and of New Zealand to Northern Australia through Norfolk Island. But so very greatly does the animal life on these islands differ from that on the continents near them (Australia, however, is 1,200 miles away from New Zealand), that the islands must be supposed to have kept their old forms of life practically unchanged, while the continents, after the islands were separated from them by the sinking of the land between, gradually changed theirs.

These continental islands, as is readily seen, embrace by far the greater part of the island surface of the world.

Another kind of island, existing in vast numbers, especially in the Pacific, is the *Oceanic Island.* These are not connected with any continent, and if they are near one, very deep water always intervenes; they occur anywhere in the ocean and often rise from great depths. They have an abundant vegetation, numerous birds and insects, some reptiles, but no native animals of the higher kinds—mammals and amphibia.*

Very many of these islands are volcanic, either containing active volcanoes or being the result of volcanic action in past ages; they sometimes rise high in the air, like the Peak of Teneriffe, a huge cone over 12,000 feet above sea-level, or are flat topped and low like St. Helena. Soundings around many of these islands show that they rise from the top of ridges on the bed of the ocean, so that, as on dry land, we must suppose the volcanic matter to have burst through the rocks of the ocean floor as they gave way and broke beneath the strain of the contracting earth beneath, and to have gradually built up what, on rising above the sea, has become dry land and the home of life.

FIG. 39. A piece of "brain coral" from the West Indies, the work of successive colonies of polyps; the surface shows the corrugations and the openings once occupied by the soft parts of the polyps. The mass below is solid, but porous.

Still other oceanic islands are the work of the coral polyp, and consist wholly of limestone. They are found only in warm seas and where the water is clear. It is strange that some of these islands rise from great depths, for the coral polyp cannot live in water over 120 feet deep. It is supposed that these islands rest upon a foundation of volcanic rock which was once near the surface of the water, and that as the polyp built up its masses of limestone the rock beneath gradually sank, but not faster than the polyp

*Island Life, by A. R. Wallace.

worked. And thus, in time, these coral islands were formed. Sometimes these islands consist of a ring of coral enclosing a body of quite deep water,—atolls. One theory regarding these says* that such islands were once a reef around a volcanic island, and when the island sank the coral polyp kept on building, and thus, finally, only the circular reef was left. Another theory says that the coral polyp always builds out from a centre toward the purest water, where there is most material for them; and so, when a colony of corals starts building in some shallow spot, they build ever outwards, till at last a circular island is formed.

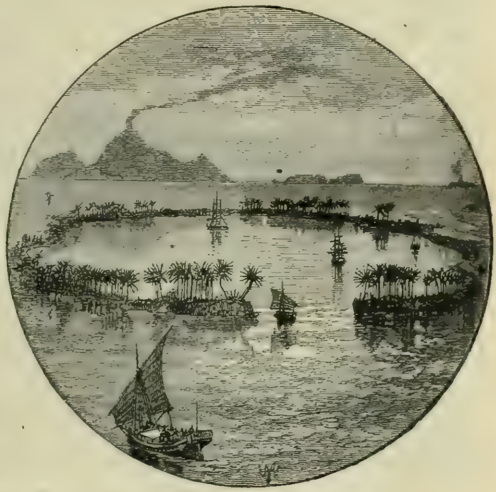

FIG. 40. An Atoll; Pacific Ocean.

The polyp can build only up to the surface of the water at its lowest. The structures are not solid masses at first, but clinging loosely together in all shapes and forms, a branching form resembling deer's horns being most common, while the material itself is full of pores and tubes which contain the soft parts of the creature. As one colony or individual dies another builds on its stony remains; the waves break off fragments, toss them on the reef or grind them to sand that fills up the vacant spaces, while the salt water is slowly melting all together into a firm, hard, but somewhat porous mass. Thus the islands grow above the water, till wind and waves and birds bring seeds and germs of life, and these, too, like the hard volcanic rock, become the home of living things.

DESTRUCTIVE AGENTS.

But whatever may have been the causes that produced and gave shape to the great earth-fold, and though up-

*Darwin's.

heaval may have given us broad plains resting on horizontal strata, or a succession of mountain and valley, such as the Jura, (where the elevations spring from the plain like great arches, so regular is the folding), or sheer cliff and deep valley through faulting and subsiding of the rocks beneath; yet it is simpler agents than these that carve into beauty and endless variety the landscape around us,—agents that, if we will, we may see at work everywhere,—the rain, the streams, the waves, the frost, the ice, the heat, the wind.

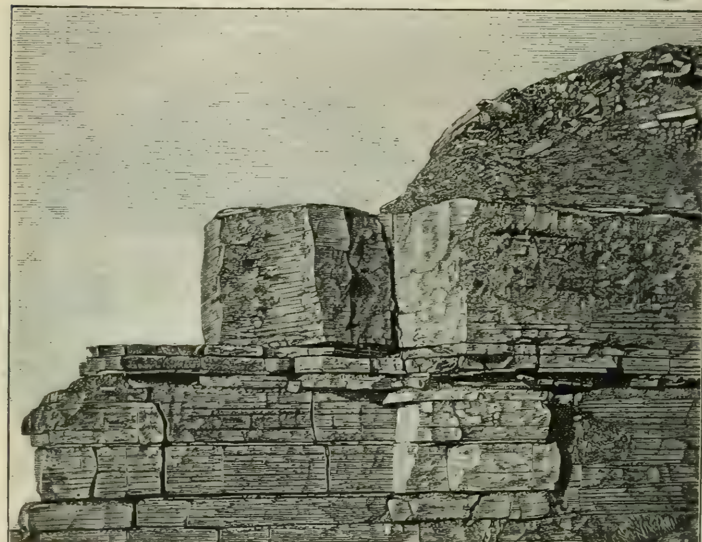

FIG. 41. Front of limestone quarry at edge of escarpment, Hamilton, showing disintegration of rock by weathering; rock almost wholly disintegrated at top.

WEATHERING. The stones and the boulders that we see lying about the fields, and the bed-rock that stands out above the soil, have all a bleached, discolored, worn and roughened appearance, their real color and texture being seen only in a freshly broken surface. We say that exposure to the air causes this appearance. But how does it do so?

The rocks are composed of many different minerals, among which lime, soda, potash, magnesia, quartz in many forms, together with iron

and other metals are very common. *Lime* is in very many other kinds of rock than those called limestone, including spar and those minerals so valuable to the farmer as fertilizers—gypsum and apatite ; *sodium* is in salt and elsewhere ; *magnesia* is present in our cream-colored limestone of Guelph and neighborhood ; *quartz* or *silica* is almost everywhere in crystalline rocks—it is beautifully pure, transparent, and colorless in rock crystal, it is milky-white and many other colors ; it forms amethysts of all shades and agates and many other stones esteemed as jewels, including garnets and bloodstones ; it forms flint, sandstone and nearly all our sand, and it is present with the important agricultural fertilizer, potash, in felspar, that mineral that makes up so large a part of the granites and gneisses of our Archæan rocks. *Iron*, too, forms part of many other minerals than those called "iron-ore ;" it is the coloring matter of very many of the minerals just mentioned; along with silica, soda, potash, lime and others it forms *mica*, and with silica, lime and magnesia it makes up an important part of volcanic rocks.*

Now, the air contains several gases, of which two of the most important, *oxygen* and *carbon dioxide*, readily unite with one or more of these minerals on coming in contact with them and thus form new substances. The heat of the sun by opening the pores of the rocks and thus letting in these gases into closer contact with the rocks greatly assists their work, as does also the rain which has gathered up a little of these gases in its fall and filters them into the rock, and then washes away the new substance that both it and the sun have helped to form. And as these gases do not unite with some of the materials of the rock as readily as they do with others, the more readily formed compounds will be carried away more quickly than the others and thus the surface of the rock will be made rough and bleached and worn.

The "decayed rock" may, of course, remain where it is; then the air will penetrate into the loose, softened mass, plants will spring up on it, insects, birds and other animals will come there, and the rain that sinks into it will carry down vastly more carbon-dioxide than it did before, because leaves and wood and vegetable and animal matter generally, in decaying produce large quantities of this gas. So deep may the decay go down that the bed-rock, with top broken and crumbled, often lies many feet below the surface of the ground.

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*Adequate representations of the minerals mentioned cannot be given in black and white, except as to the form their crystals assume. Specimens must be procured.

Of all the rock-destroying processes this *weathering* is, perhaps, the most important to us, for it makes the *soil*, which gives us so much of our food, and even of our clothing. And though in Canada the covering of our rocks is not due to their decay, but to the glacial drift, yet this drift, as we have seen, is but the rock ground down by the ice, and must itself be made far finer by decay than the ice made it, before it can become soil and bear plants. See Fig. 35.

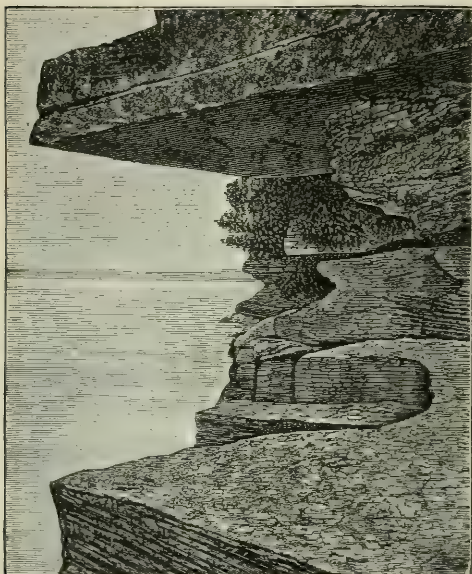

FIG. 42. Soft strata wasting away by weathering faster than the enclosing beds of harder strata. Lake St. John, Ont. Karl Lehmann, B.A., Toronto, Photo.

RAIN. But besides its chemical work, as we may call it, in weathering, rain has another, a mechanical one. To the eye the rain that falls upon a grassy slope runs off pure and bright; but if we catch a little of it in a glass and allow it to dry up, we find the bottom of the glass dimmed by a thin film—fine particles of earth that the water has gathered up and carried along with it. For however firmly the roots of grass may clasp the particles of earth, the force with which the rain splashes down will tear some of the particles away and carry them down hill; but where no protecting grass is, where the hillside is newly plowed, or a bank lies bare, so great will be the quantity carried away by even a single smart shower that the sloping sides will be deeply scored with numerous channels dug by the little streams rushing

down them,—streams that in color are like the soil itself, so filled is the water with the earthy particles that it has torn away. Even on the grassy slope, should the rain be heavy and long continued, gullies will be dug despite the protecting grass.

The driving rain makes sad work of the lettering on the tombstones of soft marble and sandstone in our old burying grounds; equally blurred or obliterated, though on far harder rock, are the pictures and characters sculptured by

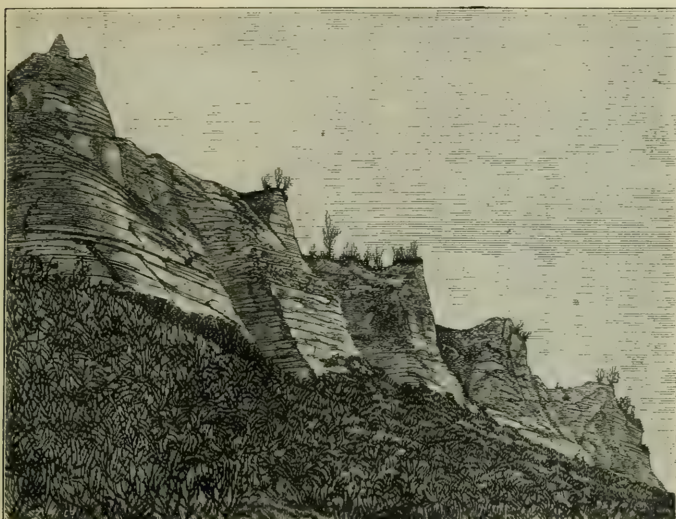

FIG. 43. A row of rain-cut cliffs of till, Scarboro Heights. There are no brooks in the hollows, only little rills during prolonged rain.

the old Hittite kings among the hills of Asia Minor, though three thousand years have been needed to do it in that dry climate. Most extraordinary is the work of the rain on the Scarboro Heights five or six miles to the east of Toronto. The lofty shores of the lake are here composed of till, a glacial product consisting of firm greyish clay and stone or shale ground fine, with some small ice-scratched stones intermixed, while beds of clay and of sand are found at different heights up the face of the cliffs.

The rain has cut this shore most fantastically:—Here it is a row of gables with sharp hollows between facing the lake; there it is a minaret or a spire standing out by itself, or again it is the side of a massive building, while rising perpendicularly from the very water itself stands a striking piece of natural architectural carving, the "Dutch Cathedral."

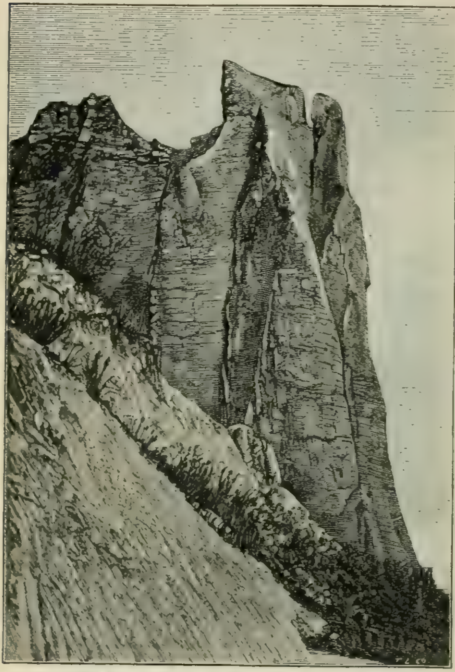

FIG. 44. The "Dutch Cathedral," a rain-carved cliff of till rising directly from the water of the lake, Scarboro Heights.

The ordinary summer rains have but a slight effect on these clay cliffs, but when the alternate freezing and thawing of winter and early spring has softened the clay, then the rain washes down the mud in torrents from the peaks, and digs the hollows between deeper and deeper and ever farther back at the top.

The same place shows us, too, another effect of rain, fortunately not here attended with any disaster, though far otherwise in other parts of the world. Great cracks come in the till cliffs, the result of freezing, and into these the rain runs, so that when the rain has been heavy and long continued the lower part of the mass gets water-soaked and thereby softened, and the slippery clay can no longer support the weight above, and the whole face of the cliff slips from its foundation and falls to the beach.

"In the year 1839, after a season of wet weather, a mass of chalk on the coast of Dorsetshire slipped over a bed of clay into the sea, bearing with it houses, roads and fields, and leaving a rent three-quarters of a mile long, 150 feet deep, and 240 feet wide," (Geikie). In 1806 the whole of one side of the Rossberg, a Swiss mountain, over 5,000 feet high, gave way and slid into the valley below, destroying four villages and burying 457 people in the ruin. For the mountain was formed of highly inclined strata, hard sandstone and conglomerate on top with soft sandy beds farther down. A rainy summer had so filled the soft lower strata that, as in the cases mentioned above, they became slippery, gave way and the mountain fell. Such land-slides have been very numerous in Switzerland.

FIG. 45. Fallen cliff of till,—a land-slide, Scarboro Heights.

Nor are these unknown in Canada on a large scale. In May, 1898, one occurred in Portneuf Co., Quebec, which destroyed three farms and their buildings and filled the valley of the Blanche River to the depth of twenty-five feet for the distance of nearly two miles; and in April, 1894, near St. Albans, on the banks of the St. Anne de la Pérade, another occurred extending over an area of three and one-half miles in length by a mile in breadth; so great a mass of earth was thrown into the river that its course has been changed.

RUNNING WATER. We say that streams are only the rain,—snow or ice,—that has fallen on higher ground and, collecting in a depression, is seeking its way to lower ground. But in seeking this lower ground streams do

much more. If we put our hand into a stream of water as it runs by, we feel the water pushing against it, and if we try to wade across the stream we have to set our feet very carefully and brace ourselves against the water lest it should push us down, "carry us off our feet," as we say. When after a heavy rain or a sudden melting of snow, the streams are full and are rushing down their steep beds on hill or mountain side, so great is their strength that they push helplessly forward not only the smaller stones of their channels, but even large boulders that have fallen from the banks above, or been torn from the bed or sides of the stream.*

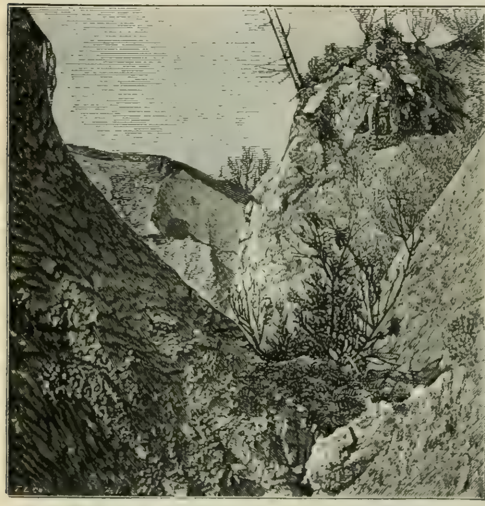

FIG. 46. A cañon-like ravine in till, Scarboro Heights. A small brook (not shown in figure) has cut its way almost down to the level of the lake.

While stones and boulders are being pushed along, they are rubbing and grinding against each other and against the rocky bed, and the sides of the stream whether of earth or rock. In the process both stones and boulders are ever growing smaller and smaller, while their place is taken by others which are torn from the rock beneath or from the sides, or which roll down from the higher ground above as the banks are worn away, or as the frost or the rain loosens them from their resting places. The bed of the stream, too, through tearing up or wearing away of the rock†

*It must be remembered that in water a stone weighs less than it does out of water by as much as a quantity of water the size of the stone will weigh.

†This process of wearing away by rubbing is called "*erosion*," though some United States geographers use the term "*corrasion*" instead, reserving "erosion" to the general lowering of the surface.

is slowly, though surely, becoming lower and lower, while at the same time the rain is washing down earth from each side into the stream, and thus while the bed is deepening the banks are continually growing more and more flaring.

In summer when only "seasonable showers" occur, and the ground can drink in all the rain that falls, so that there is none to spare to turn the brooks into torrents of muddy water, but each stream is clear and bright, there is very little of this wearing away, or erosion, at either bottom or sides. For somehow the stones, and even the sand, have all got settled down into little beds or are bracing themselves one against

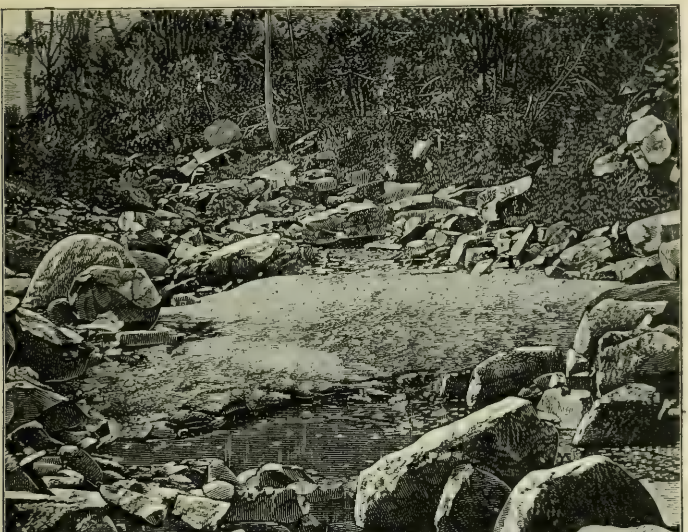

FIG. 47. Bed of brook at Grimsby; limestone boulders in bed and at sides, fallen from escarpment which the stream has channelled; bed rock of red sandstone in middle, much worn by erosion.

another so that the water does not move them. And a slippery covering comes over the stones,—a thin layer of mud or of a lowly vegetable growth,—that protects them from the scour of the sediment, which, as we have seen, is still in the water however clear. Only, where the shallow water is gurgling around the corner of a quietly sleeping stone or is falling over it in a little cascade, and close to the bottom the sand is whirling and dancing in the miniature eddy,—only here is there no slime on the stones, and the wearing away is still going on.

But when the rush of the swollen stream comes, whose waters are dark with the waste of soil and rock, the slippery stones are scoured

clean, for strange as it may seem, this waste, or sediment, though soft to the touch, the microscope shows to be sharp and angular. It is no wonder, then, that water filled with sediment will cut so rapidly into the rock whether at bottom or side.

Some years ago an English steam launch, while exploring the mouth of a Chinese river, was caught in the furious bore that the rising tide brought in. The anchor was thrown out which fortunately held the little vessel fast; but when it was drawn in again, the chain and all the anchor that had not been buried beneath the mud at the bottom, were found to be polished white and bright. A rush of less than half an hour of the muddy water had done this singular and unexpected act.

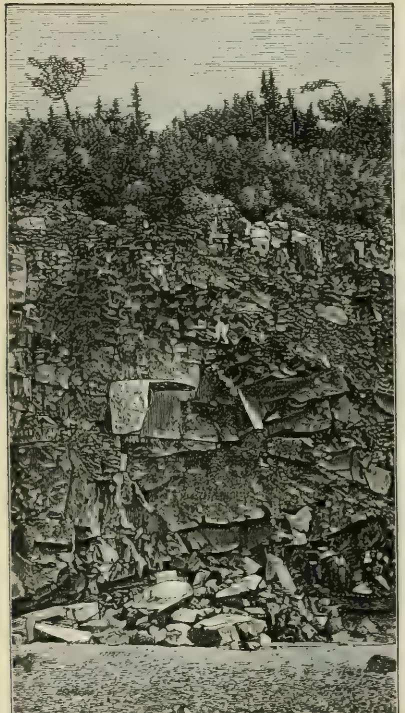

FIG. 48. Mass of rock fallen from face of cliff to beach; cliff is of basaltic trap, about 150 feet high, Bay of Fundy, Hall's Harbor, King's Co., Nova Scotia.

FROST. Our farmers know well how a stiff clay soil bakes under the hot summer sun till it becomes almost as hard as a stone, and how great is the labor to prepare for fall sowing a field with such a soil. Yet if the plowing is done in the fall, the moisture in the upturned earth will freeze and the soil will thus expand, and when in the spring it thaws again and dries, it will be found open and crumbling.

Water soaks into all rocks more or less, and finds its way into all cracks large and small, and the frost of winter will follow it and freeze it, as it does the moisture in the soil. Fragments of rock will thus be forced off and will lie loose, if on the bed-rock, or, if on a hill-side, will be thrown to the valley beneath forming that slope of waste

called the *talus*, which we see at the base of every cliff where running water does not take it away. Dwellers near the edge of the basaltic cliffs that fringe the coast of the Bay of Fundy, are often startled in early springtime by a roar coming up to them from the shore, and they know that a mass of rock has been hurled to the beach from its place in the face of the cliff. And seekers after mineral treasures are early at the base of Cape Blomidon in the spring to search among the masses of rubbish that, along with great boulders, have slipped from their place above, pushed outward by the expanding force of the freezing water.

Among mountains the most fantastic peaks and the wildest scenery are found where the frost has done its work on the hardest crystalline rocks; and basaltic trap, a rock so hard that thin fragments of it ring like metal, will split up, under the action of frost, into scales with edges as sharp as a knife. Sir Walter Scott is a better poet than geologist when he calls the frost-shattered tops of the cliffs in the Trosachs "thunder splintered pinnacles."

ICE. The terribly destructive character of moving ice, or glaciers, has been referred to in dealing with the Glacial Era,—how it tears up the rocks beneath, and while grinding the fragments into mud against the bed-rock, wears down that bed-rock itself; and how it carries in long loose lines on the surface, or buried in the blue mass itself, great quantities of stone and rubbish that, loosened by the frost from their places, have fallen from the mountain side, to deposit them in heaps, sometimes hundreds of feet high, far down at the mouth of the mountain valleys.

In the form of icebergs,—great masses of ice that break off from the ends of glaciers whose valleys open into the sea,—ice may carry considerable quantities of stone buried in them, far away from their original home and drop them in the deep sea. The banks of Newfoundland must be made considerably shallower from the abundance of ice-borne material that the melting bergs here drop into the water. The common floating cake-ice of our rivers, lakes and seas, is often driven ashore by wind or currents, and there freezing to the boulders of the beach, carries some of them away when the next tide or the next change of wind

sets all afloat again. Among the trap-boulders of the beach along the Bay of Fundy, red granite boulders, large and small, are everywhere met with. These can come only from the New Brunswick coast of the bay near the Maine border, or from the Cobequid Mountains far up at the head of the bay, and floating ice can be the only means of transport. Seldom does a mass of rock that has fallen from a cliff to a beach where ice-cakes pile up in winter, remain long where it has fallen unless the fragments are of great size, too large for cake-ice to carry away.

In favorable situations ice will form at the bottom of shallow running water, and from becoming quite thick, or from other causes, will rise to the surface, bringing with it quantities of mud, sand or stone, and will carry them wherever it may drift. The shores of the lower St. Lawrence show this work of ground-ice to a very marked extent.

HEAT. Not all countries have frost to shatter the rocks, or rain to wear down the hills and carry acids down into the ground to help destroy the bed-rock. Northern Africa and Arabia are both hot and dry, and here the range of temperature is so great that during the day the heat is almost unbearable—from 120° to 130°—while during the night the heat passes off so rapidly under the cloudless sky that the thermometer falls to the freezing point. Rocks cannot stand this change of temperature; they split in the sudden contraction just as a piece of heated glass splits when a drop of water falls upon it, or they scale off in thin chips, large and small,—a fruitful source of the desert sand. The same effects are seen in rocks in elevated regions, especially in dry climates, for in the direct sunshine the heat is very great, but the cold comes on almost instantaneously when the sun disappears. Where along with the heat there is moisture too, there is not only a destruction in rocks caused by their cooling through a sudden fall of rain, but the heat makes the effect of the acids in the rain much greater.

WIND. We all know, through unpleasant experience, how the wind raises great clouds of dust and drives it with stinging force into our faces. The microscope shows that the dust of our city streets and country roads

and fields, though composed of many materials, consists for the most part of minute grains of sand with very sharp points. It is these that sting so when they strike our faces. A little stream of sand falling from our hand upon a piece of glass or any other polished surface, will soon make it dim; the sand scratches the glass,—cuts out minute particles of it, thus destroying the polish. If such a little stream of sand be driven with great force against one spot, the glass will speedily be pierced,—a process actually employed in factories.

An obelisk that had for many centuries lain half buried on the sand in Egypt was transferred to a park in New York; the hieroglyphics on the parts that had lain buried are seen to be quite sharp and distinct, while those on the exposed parts are blurred or even wholly obliterated. The driving sand had done its work on this hardest of rock. In dry, wind swept regions such as the deserts of Africa and Asia, and the plains of the western United States, the driving dust and sand cut away the base of exposed rocks, and if such are loose boulders or isolated masses they eventually topple over, only to be again attacked.

What are called "sand blows" in some parts of the United States, but found the world over, literally strip the soil from newly cultivated land and leave the young crop, if any is left, clinging to the ground by a few long under-roots.

But the wind does not cut down merely; it carries far and wide the dust that it has made or that the other destroying agents have made. Indeed, dust is everywhere present in the air, for the winds circulate everywhere over the earth; nothing can shut it out. The coarser parts that are swept from streets and fields are not carried far, but are soon dropped in other places, slowly raising their level; but the finer particles are spread over immense areas. The vast amount of dust hurled high into the air by the destruction of Mt. Krakatoa, in the year 1883, was carried by the winds around the earth, giving us for weeks here in Canada, on the opposite side of the earth, strangely beautiful evening skies.

During the eruption of Tomboro, in the Island of Sumbawa, in 1815, dust was carried by the winds over 800 miles, and houses forty

miles distant were crushed in by the weight of matter falling on them. The dust covered an area of 1,000,000 square miles, and amounted to fifty cubic miles of material. In 1783, dust from Skaptár Jokül, in Iceland, fell in such quantities on the North of Scotland, 600 miles distant, that it covered the ground and destroyed the crops. The fine red dust swept from Sahara is carried far out to sea by the winds, where it often falls on shipboard and sometimes is brought down in the rain,—the "blood-rain" we occasionally hear of in the newspapers as a very wonderful phenomenon. Nor is it any wonder that among the dust blown from more favored regions than the Sahara, the microscope shows that germs of vegetable life exist. What a provision is here made for diffusing life over the earth !

FIG. 49. Sand-dune partly burying trees, Point aux Pins, Kent Co.
Norton, Ridgetown, Photo.

Another peculiar phenomenon due to the wind is the building up of sand-dunes,—great ridges of sand along the shores of our bodies of water, lake or sea, blown by the wind landward from the beach. A long, gradual slope faces the windward side, but the lea side is steep. The sand drifts up the windward slope and on reaching the top falls over on the other side; so that a spectator looking along the ridge will see a mist, or thin cloud, rising a little above it and suddenly disappearing, while on one who is passing along under shelter of the dune a storm of sand is continually falling.

Thus, it can be readily seen how a dune may advance inland to a considerable distance from the shore. It does so to some extent in Canada,—in Prince Edward and Kent Counties, for instance, where trees are buried and fields and houses covered up. Dunes fringe the

New Brunswick shore of the Gulf of St. Lawrence; in England they have buried and then passed over whole villages; in Holland they are in places five miles wide, forming a barrier to the North Sea, the sea following close, however, as the dune passes on; the people of the Baltic coast of Germany keep up a continual, almost vain, fight with them; but in south-west France, in the "Landes," along the Biscay coast, they have been in some places overcome. For, more than a hundred years ago, the French government set out a vast number of trees on these endless sand hills, cared well for them, and now the trees not only check the sand, but afford a large supply of timber.

It will be readily inferred that the dry sandy deserts are the especial home of dunes. There they are like great waves of the sea in shape and distribution, and in movement,—for they move over the desert, though more slowly, as the waves move over the sea. Unfortunately the resemblance goes farther, for the immense masses of sand that are borne onward in a storm, sometimes fall on and overwhelm the caravan, just as a mountain wave may fall on and overwhelm a vessel.

Thus, like running water, the winds tear down the land and transport it to other places; but with this difference, the burden of the wind may drop upon any surface, high or low, land or water, while that of the running stream falls only on a lower region, and only rarely falls upon land.

THE WAVES. While running water wears the rocks down by ceaseless rubbing, the waves as they fall upon the beach or dash against the wall of the confining cliffs, almost literally pound or crush the rocks to pieces. During the storms of winter the force with which the breakers dash on the beach or against the cliffs is calculated to be three tons or more to a square foot. It is no wonder then that we hear of great masses of rock weighing hundreds or even thousands of tons being burst from their position on the face of the cliff, or rolled about upon the beach as if they were trifles. Such a tremendous force crushing the grains of sand and the stones and boulders of a beach against one another must speedily reduce them to fine mud, while the bed-rock is ground down to a smooth floor beneath. Very instructive is a sight of the beach at Oakville when a strong wind is on shore. The narrow, steep face of the beach, composed wholly of loose disk-like stones, is in wild commotion; the in-rushing waves while crushing the stones against one another, drive them up the steep

slope of the beach and then with even a louder rattle than before the returning flood drags them down again as it pours back into the lake, while all the water for many yards out is black with the waste, an evidence of the rapidity with which the stones are being destroyed.

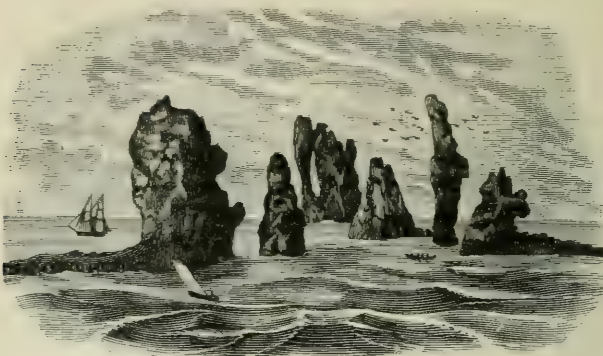

FIG. 50. Island destroyed by waves; north of Scotland.

But while a rock-bound shore retreats only slowly, at best, before the waves, a shore of loose material,—drift, clay, etc.—yields rapidly, as the dwellers on our lake-fronts know full well; many feet are washed away each year in spite of all the efforts of timber, or brush, or stone to prevent it.

121) Volcanoes
- build up by [illegible]
- land around [illegible]
- tearing down

Building up	Tearing Down
stream	[illegible]
ice	[illegible]
[illegible]	frost
volcanoes	[illegible]

CHAPTER III.

MOUNTAINS.

The term "mountain" has no very precise meaning; in low-lying Ontario any elevation rising two or three hundred feet above the surrounding country is locally called a "mountain," the Blue Mountains, for instance; and to those who live along the western shore of Lake Ontario, the escarpment of the old Lake Iroquois, though the top is only the general level of the country back of it, is a "mountain;" in flat Denmark one elevation five hundred and fifty feet high is named "Heaven's Mountain." In western, or even in eastern Canada, such would be called at best only hills; some of the foot-hills of the Rocky Mountains are 1600 feet high, approaching in height the lower peaks of the mountains themselves.

Fig. 52. Mt. Ross, Canadian Rocky Mountains. A typical mountain with double peak, forest clad for the most part. Thompson, phot., New Westminster, B.C.

Mountains occur in nature in different forms:—as *single elevations* rising from a low plain as do Montreal Mountain, the mountains of Belœil, Mt. Johnson, &c., in Quebec, and Mt. Katahdin in Maine, or from a high plain, or plateau, such as the western plateau of America; such mountains are either of volcanic origin or are remnants of what was once far higher ground:—as *ridges*, elevations whose top may stretch away for many miles in an unbroken line, or

be broken into numerous peaks whose base does not go down to the base of the ridge, such as the North Mountain, a trap ridge of over a hundred miles in length along the south shore of the Bay of Fundy, and the numerous ridges of the Sawback Mountains:—as *ranges*, successions of peaks or ridges of no very great length, following one general direction, one ridge often beginning before another ends, thus overlapping or jogging into one another, such as the Fairholme and Fisher ranges where the Canadian Pacific Railway enters the Rocky Mountains, the Sawback Range and many others in the line of the same railway:—as *systems*, either two or more ranges, or, with geologists, all the ranges found in the same region that have been formed in the same geologic age but by different earth-movements; thus in the western mountain region of Canada is the Rocky Mountain system (some fifty miles wide), followed westward in succession by the systems of the Gold Ranges, the Coast Ranges, and the system, largely submerged, of which Vancouver

Fig. 53. Pinnacles in the till at Scarboro Heights, in a recess between two much larger cliffs.

Island and Queen Charlotte Islands are a part:—as *chains*, with geologists, an assembly of parallel or nearly parallel ranges or systems of different geologic ages; but ordinarily, "chain" means the same as range:—as *cordilleras*,—a term not in common use,—two or more chains associated together forming one mountain mass, such as the mountain mass of western America.

ORIGIN OF MOUNTAINS. Fig. 43 shows how the lofty shores of Lake Ontario at Scarboro Heights look to one who gazes up at them from the beach below—a miniature mountain ridge which the rain has carved in the till that here forms the edge of the general level of

the country where it drops suddenly down to the lake below. From the top of the banks, however, no such ridge appears, only some little knife-like peninsulas, as it were, stretch outward from the main edge toward the lake. Here and there, as seen in Fig. 53, the inner part of the knife-edge peninsula has been worn away by the rains and fantastic little peaks or pinnacles are the result; or again, a stream has cut its way down through the till almost to the level of the Lake (Fig. 46), and now a cliff rises sheer from the beach, and where the inner part of the peninsula has been worn away too, as seen in a measure in Fig. 44, a little mountain stands out from its surroundings.

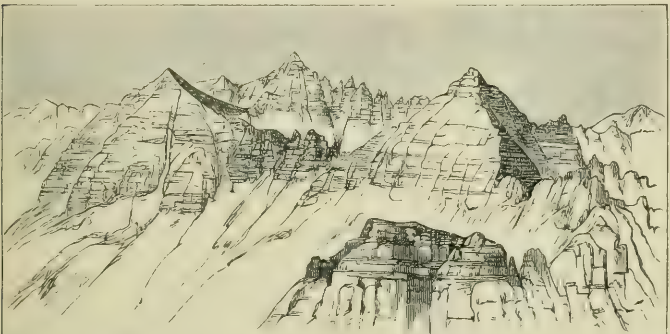

Fig. 54. Mountains on the edge of a ravine in the Rocky Mountains, western United States.

Now if this little Scarboro district could be stretched out some hundred miles or more, and raised five or ten thousand feet in air, and if the soft till could be turned into hard rock with all its present faces and peaks and hollows proportionately enlarged, we should have a plateau flanked by a ridge of mountains, — here, a regular succession of peaks connected upwards for half their height, there separate peaks or a huge mountain standing out from others, while every now and then a deep gorge or "gap" or "pass," with its rushing stream, would lead far inward from the front.

The mountains outlined in Fig. 54—the result of erosion—in their pinnacles, their fantastic cliffs, their bold triangular fronts with sharp ridges running into the background, strikingly resemble what the Scarboro Heights show us; but the material is rock not till, and it rises thousands of feet in the air, not merely two hundred. And thus it is seen wherever a plateau rises from the surrounding country, whether it be the Himalayas on the flank of the great plateau of Thibet in Asia, the Sierra Morenas and others skirting the plateau of Spain, or the Rocky Mountains in America, where in places "cliffs of limestone fifteen hundred feet high face the plain to the east," and where travellers by rail have crossed the mountains by the Bow River "gap" and the Kicking Horse "pass."

UNEQUAL EROSION. The manifold and often marvellous forms into which the rocks are carved, are due to various causes. The rocks vary greatly in hardness, or rather they yield with different degrees of readiness to the weathering agents. Thus the Cretaceous rocks among the Rocky Mountains, though much younger than the others, are softer and so are worn away far more deeply; the "foot-hills," a belt of hilly country fifteen miles wide in Canada at the eastern foot of the Rocky Mountains, and formed at the same time as they, are very much lower, for they are of Cretaceous rock, while the others are of hard Devono-Carboniferous limestone. The different joints* of the rocks greatly influence the character of erosion. Not all rocks have the same kinds of joints, and hence the eroding and weathering will be very different; while some rocks, as limestone, will weather into blocks, others will become rounded, angular, or splinter into many forms. Again volcanic rocks weather differently from stratified rocks; some beds are massive, others thin; some rocks are in horizontal beds, others curved or thrown on edge, even overturned, or

*Rocks split in different ways:—along the planes of bedding, the beds being due to irregularity or interruptions when the sediment was being deposited, each tide, for instance, forming a new bed;—at any angle to the plane of bedding, due to great side pressure seen well in slate rocks; this is called *cleavage*:—along joints, as seen in Fig. 41, forming cubical blocks, the cause not being well understood. Some rocks have few if any joints, such as granite, which often forms unbroken mountain masses, the boulders weathering to a rounded shape.

contorted and twisted to a surprising degree, and lie in all possible positions; they are faulted or lie unbroken; they are exposed in various degrees to the action of water, to the winds and the storms;—these and others all contribute to the wonderful variety in mountain forms and mountain scenery everywhere witnessed.

EROSION MOUNTAINS. On the tops of plateaus the cutting down and carving go on as well as along the edges, but more slowly, for the slopes are not so steep. The great length and breadth of these folds or wrinkles of the earth, whose upheaval has been so uniform that the strata remain almost, if not quite, as level as when they were laid down beneath the water, allows them to have streams of all sizes running along natural depressions in all directions—lengthwise, across, and diagonally; so that if these streams alone were at work, they would in the course of ages cut the plateau into huge blocks separated by chasms the width of the streams and of dizzying depth, such as are really found in dry regions, notably along the course of the Snake and the Columbia Rivers in the dry western plateau of the United States.*

But we know that the streams alone are not the only forces at work. Every brook and stream shows us the rain and frost and wind busy widening out and sloping down the cut that the water has made, till at last the brook is only a narrow band flowing at the bottom of a broad hollow, so broad sometimes that we wonder if the brook had ever been large enough to fill the hollow from lip to lip. So while the streams are doing the downward work on the plateau, the other agents are extending that work sidewise, so that, after untold years, ranges or masses of mountains will stand where once the plateau stood, and the streams that did the work may still be flowing at their base, rapidly if their work is not yet complete, but slowly and through a wide, level-floored valley if complete—if they have cut down as far as running water can go, to "the base level of erosion;"

*See further under "Rivers."

in either case the streams will look all too small, too insignificant, to produce the result that they, nevertheless, have certainly produced.

Groups or lines of mountains thus formed—*mountains of circumdenudation* as they are called—stand out against

Fig. 55. Mount Stephen, on the line of the Canadian Pacific Railway, fifty miles west of Banff; showing the nearly horizontal strata, the dome shape, the cliffs and shelves of rock, with glaciers. (Cf. Fig. 57).

Thompson, phot., New Westminster, B.C.

the sky with their tops on the same level; their various strata appearing in corresponding places in each, and where massive, "the level bars looking like gigantic courses of masonry." In the Canadian Rocky Mountains, wherever such as these are found, "the four or

five thousand feet of rock rising above the base-level of erosion in the valleys, is cut into irregular-shaped, steep-sided blocks, terminating in blunt or flat summits, or covered with broken cliffs."* For here the beds are horizontal, and will readily split apart and become shattered (Fig. 41); or the softer beds yielding more readily to the weathering influences, will drop away in a slope from the harder ones above, till the latter, often left as a rocky ledge or shelf on the mountain-side, being undermined and thus deprived of support, will break off and fall, leaving a sheer cliff behind them, which in the course of time will meet the same fate (Fig. 67). Many of the mountains of New England have been thus formed, and all the Laurentides of Canada, though the latter do not have the blocked structure as do those referred to above.

MOUNTAINS OF DISTURBANCE. But the great mountain systems of the world have not had this simple history—a plateau of horizontal strata of varying degrees of hardness carved into shape by running water and atmospheric influences. For their strata, beside being upheaved, have been subject to distortion often of a most violent kind, so that the forces of erosion and denudation have been greatly hindered or greatly helped in their work upon the rock by the manifold positions into which distortion has thrown them. The carving and cutting here take the most fantastic or confused shapes; — great angular, rugged masses piled indiscriminately together, knife-edge ridges towering over deep narrow valleys, folds with valleys dug into their tops, the broken edges of the strata sloping away in rough terraced walls, or the valleys dug so deep that the trough of the fold has become a mountain with the strata on both sides curving inwardly; or faults occur giving sheer cliffs hundreds or thousands of feet high, bending the strata in on one another or on themselves, overturning them and pushing them, in "thrust" faults, sometimes for miles, one over another, so that strata of widely different ages are brought into contact,

*Geological Survey of Canada, 1886, Vol. II.

or, where the denudation has been very great besides and has exposed the interior crystalline core of the uplift, tall slender spires and "splintered pinnacles" rise high in the air, giving the "needles" and the "horns" so common in the Alps, or huge masses or shoulders of granite will stand out as if defying the agents of destruction.

UPHEAVAL REPEATED. Nor have these mountains been upheaved, fractured and contorted by one single convulsion of the earth however long continued. In almost if not quite all, geologists find evidence of repeated upliftings and repeated fracturing, some even now in progress. For where in its contraction the crust of the earth has given way and crumplings have arisen on it, it would, naturally, again break along the same lines when it once more settled down on the mass below; for it was the weakest spot, "the line of the least resistance," that gave way in the first place, and such breaking would only make an original weakness still weaker. The manifold positions that rocks are thrown into by compression and upheaval, and the forms they assume in consequence through erosion and denudation will be best seen from a sketch of a section of the Canadian Rocky Mountains.

THE ROCKY MOUNTAINS.* The Rocky Mountains are mountains of disturbance. They form the eastern system of the great American cordillera, with a breadth in Canada, in the southern portion where they are best known, of about fifty miles, from the foot-hills on the east to the Columbia River on the west. The whole region here seems to have received a mighty thrust from the west throughout the entire depth of its strata, which has manifested itself in many ways in its effects upon the rocks towards the east.

At the western end of a line following on the whole the course of the Canadian Pacific Railway eastward across the Rocky Mountains through the Kicking Horse and Bow

*The matter of this description, together with the diagrammatical figures 56 to 63, is drawn mainly from an exceedingly interesting report in the "Geological Survey of Canada, Vol. 2, 1886," by R. G. McConnell, B.A. The scale of the diagrams both horizontal and vertical is two miles to an inch.

River valleys, are the Beaverfoot range and Mount Hunter (Fig. 56). In the former the ridge is composed of beds of hard Silurian limestone that have been broken and thrown up at a steep angle, some of them being crumpled and bent in on one another greatly increasing their thickness; under these on the left is a bed of Cambro-Silurian

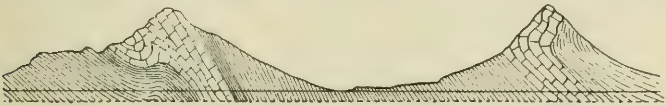

Fig. 56 Beaverfoot Range, 5000 ft. high, on left, Mt. Hunter, about 6000 ft. high, on right, Kicking Horse (or Wapta) Valley between.

rock in its natural order of formation, while on the right the very same rock lies on top of the Silurian; so that during the commotion in these strata the very much older bed has been overthrown and piled upon a younger bed. In Mt. Hunter the crest is formed of beds (Cambrian) that have not only been steeply tilted but also bent almost at right angles. The valley between has been deeply excavated in older and softer Cambrian strata that rise high on the flanks of both mountains.

Some fifteen miles further east rises an immense fold, like a mighty wave, broken near the middle by a great

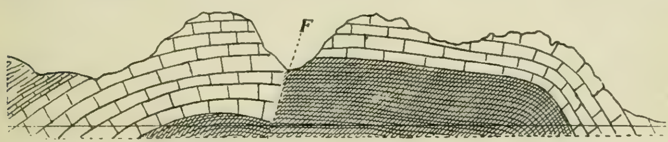

Fig. 57. Mt. Stephen on the left, Cathedral Mts. on the right, a fault, F, between them; strata all Cambrian but of different formations. See Fig. 55.

fault, the part to the left, forming Mt. Stephen, having a "downthrow," as it is named, of over 3000 feet, while the part to the right forms the rough-topped Cathedral Mountains. On top the strata are parallel, or nearly so, and hence, as has been said, these mountains may in a measure represent "mountains of circumdenudation;" but the sides curve downward and away from each other

towards what would be a trough, thus forming an "anticline." A deep valley has been eroded along the fault, the fault helping in this very greatly, while another valley is being dug along the Cathedral Mts.; the mountain on the left of this latter valley will be a real "mountain of circumdenudation" with its flat-lying strata, while the one on the right will be an "anticline" mountain.

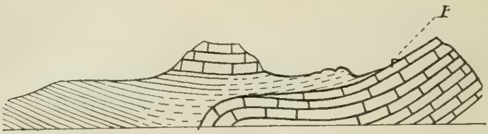

Fig. 58. Slate Mt., Cambrian resting on still older Cambrian beds; other strata, Devono-Carboniferous, the upper layer being Devonian; F, a "thrust fault."

Farther east, a little to the north, is Slate Mt., a gigantic block of Cambrian strata resting on still older Cambrian beds; the great thrust from the west caused a fault (F, Fig. 58), overturned on the right the strata of a much later age, and pushed the older strata for more than a mile over them, so that, as in the Beaverfoot Range, newer strata lie below older. Beside this the strata of the mountain are not flat; they curve inward toward the middle, making a "syncline" mountain. Thus, strangely, this mountain was once the bottom of a trough between two folds, or ridges; the ridges are gone and what is a mountain now was once a valley. The strata in the valley may have been the hardest, or they were covered up by the

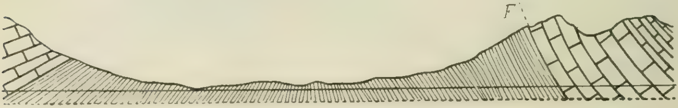

Fig. 59. The valley of the Bow near Mt. Stephen.

waste washed down into the valley from the ridges, and were thus protected from erosion; or the strata on the top of the ridges were broken or shattered by the strain of bending over, and so were in a state to be more quickly eroded than the strata in the trough, which were compressed and so made harder by the upward bend.

The valley of the Bow River a little east of Mt. Stephen, shows what appears at first sight to be a strange phenomenon, but what is nevertheless very common in mountain regions — a valley, through which a stream is flowing, where once rose a great rounded fold;—the whole of the fold has been denuded and carried away; it is the converse of what is seen in the case of Slate Mt.

Immediately to the east of this valley is Pilot Mountain, rising on the side of a syncline, or rather a compound syncline, its upper strata lying almost horizontally, but the range to which it belongs, the Castle Mountain range, is a great mass of limestone blocks gently bending inward —a syncline range. The strata of Pilot Mountain dip down under the Bow River valley, but when they reappear they are no longer curved but stand up almost on end at a

Fig. 60. Pilot Mt. on the left, Sawback Range on the right, Bow River valley between. Lower beds (blocked) Cambrian; shaded and crossed next above, Devonian; rest Devono-Carboniferous.

very high angle, just as if they had been broken short off beneath the valley, the western ends falling deep down and the eastern ends tossed high in the air. It is the Sawback Range,—a "monocline," beds tilting but not curving to or from a centre,—"a range between two and three miles wide composed of about 11,000 feet of strata varying in hardness from quartzite and crystalline limestone down to soft shale. All the different degrees of hardness in the beds are now seen very plainly in the unequal denudation. The softer bands have sunk into deep irregular furrows, while the more resisting beds thrust themselves up in long lines of sharp-pointed peaks." The massive character of some of the beds is in marked contrast with the "thin wedge-like summits" of others, and "aerial peaks" bounding a valley on one side stand over against gigantic walls of rock that bound the valley on the other. "When viewed from some higher

summit the appearance of these crested ranges with their lines of jagged peaks united by thin zigzag knife-edges on which it is often difficult to find a footing, is wild in the extreme."

So violent here was the eastward crush that tilted up the Sawback Range, that not only were the faulted strata of the valleys alongside to the east (Fig. 61) caught and doubled in on themselves, but the whole series of beds was reduced to one third of their original thickness. The strata of the Cascade Mountain seem to form an anticline curving down under the valley of Forty-mile Creek on the west, but in their upward curve from this valley they have been broken and faulted and their broken ends lie under strata of a later date, while to the east these latter beds have been faulted over upon Cretaceous rocks, of a very

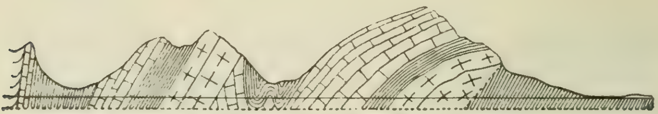

Fig. 61. Vermilion Lake Range on left 4000 ft. high, Cascade Mts. on right 5200 ft. high, Forty-mile Creek between. Blocked and shaded beds, except the shaded one on right, which is Cretaceous, Devono-Carboniferous; others, Devonian: two faults, not marked, but evident.

much later date still. The soft beds that lie in the valley of Forty-mile Creek, once extended over the harder beds to the top of the mountain to the east, but they have all wasted away; the same beds form the valley on the left, while another bed, softer than the limestone beds around it, by wearing away faster has made a notch in the top of the Vermilion Lake Range, and thus given rise to two hard ridges where once there was but one.

Stretching eastward for many miles from this is a series of mountains, monoclines, formed of broken blocks of tilted strata, the eastern end of each resting upon the depressed western end of the one in front, a valley lying along the base of the upturned ends. The eastern face of these ridges is steep and rugged, the western is a long gentle slope. This appearance in nature is seen to some extent in Fig. 62.

Mountains similar to these occur in Oregon and elsewhere, but the valleys at the base of the uptilted ends are not eroded valleys such as these are, but are due just to

Fig. 62. Southern face of the Fairholme Mountains along Lake Minnewonka, (Devil's Lake) to the north-east of Banff, showing broken and tilted strata.
Thompson, phot., New Westminster.

the tilting; the rocks show very little evidence of erosion, and hence it is inferred that such mountains are of very recent origin, though the cause of the breaking of the strata is unknown.

The Fairholme Range rises steep over the foot-hills, and faces the plains to the east with bold escarpments from

Fig. 63. The Fairholme Range along south fork of Ghost River; on top to the right and where similarly marked near centre, Devonian; below this, blocked, Cambrian; above to left, shaded and blocked, Devono-Carboniferous; extreme left, Cretaceous; the mass has been faulted and pushed over Cretaceous at bottom on right, wavy marked.

2000 to 4000 feet high. It repeats the Sawback Range in the wild scenery of its sharp peaks and knife-ridges with deep valleys between; but its most extraordinary feature is a great thrust-fault along which a ruined fold of old

Cambrian and Devonian strata has been pushed out toward the plain over the newer Cretaceous beds for a distance of seven miles. This was the last effort of the great thrust from the west.

Mountains that have burst open, as it were, or where the denudation has been so great as to uncover the crystalline rocks beneath, do not appear in the part of the Rocky Mountains described above; but in the Alps they appear in a very striking way, and crystalline rocks whose tendency is to split and splinter in the frost form all or nearly all of the famous peaks of those mountains, so many of which bear the name of "horn" or "needle."

The forms and positions that we have just seen are only a few out of the infinite variety that rocks take under the

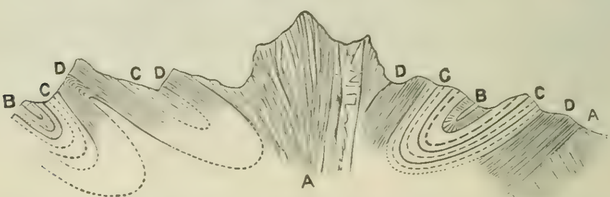

Fig. 64. Diagram of Mt. Blanc, Switzerland, showing fan-like structure. A, crystalline core; B, C, D, folded and overturned strata once continuous over the crystalline, now removed by denudation.

influence of the mighty side pressure that sinking strata exert; every rod, almost every foot, shows some new shape into which they have been bent and contorted; but when through decay and removal thousands of feet of rock have disappeared, all connection between what were once continuous beds may be wholly lost.

EROSION AND UPLIFT. It must not be supposed that the erosion and denudation begin only after a plateau or a mountain has reached a standstill in its upward progress; both begin as soon as the land shows itself above water; so that no plateau or mountain of stratified rock ever existed unscarred and uncarved by "the powers of the air." While elevation was going on the erosion was going on too, and it is only because the former went on at a more rapid rate than

the latter that any high ground exists at all. Had the two forces been equal the newly risen ground would have been swept away into the sea again as fast as it rose, to fill up the hollows on the ocean-floor. But in their rise plateaus and mountains carried up with them alike the cliffs and channels that were being cut in them and the streams that were doing the cutting.

OLD MOUNTAINS. It may well be imagined, then, that those mountains whose rise was earliest in the world's history, must have a very different look from those of a later age, — that the Alps, and Himalayas, and Rocky Mountains, those youthful yet

Fig. 65. Old worn-down mountain ridge (Cambrian), with valley of the Gaspereau River, King's County, Nova Scotia. River at base-level, floor of valley an alluvial flood-plain. Slope in foreground is bottom of ridge similar to other; course of river shown chiefly by bordering trees. Note the difference in appearance between this ridge and the various illustrations from the Rocky Mountains, especially in Fig. 62.

deeply furrowed elevations, must be different from the mountains of eastern America whose date goes back, as we have seen (page 23), to Silurian days. It is in the former that we find the "aerial peaks," the wild crags, the massive walls, the gorges, the canons of dizzying depth, and everything awe-inspiring and grand that we associate with mountain scenery; while the older ones, whose strata are all those of early Palæozoïc days, have a subdued look; they are never lofty, their forms are rounded, their sides have no walls of rock, for these have been all worn off or

have been covered up by the waste; their valleys have broad level bottoms and wide flaring sides; the rivers in their lower courses are sluggish, as they are down as far as they can well go, to their base level, though in their upper courses they still are rapid and have steep but not high rocky sides and little waterfalls; forest-growth covers them; human industries and human dwellings have crept far up their sides and even to their very tops; lumbering, mining, farming are there, for the slopes are not so steep but that soil will accumulate and bear trees, and these give place to the fields of grain, while the long-continued denudation and erosion bring to light the stores of mineral wealth,—coal, iron and others,—that would otherwise have remained hidden beneath thousands of feet of rock.

All the mountains of eastern Canada, as we have seen, are old mountains. Nova Scotia is almost wholly the worn-down extremity of the old eastern mountain system of America; though here, as everywhere in Canada, the ice has had a great deal to do with the general appearance of the country. The surface is rolling with a gentle rise from the sea on all sides, its highest part swelling up into a granite ridge that traverses the country almost from end to end, while another similar ridge forms the central mass of the Cobequid Hills. Broad river-valleys are numerous, though now from gradual sinking many of them are "arms of the sea." Such is Halifax Harbor, and doubtless also Minas Basin with its extension, Cobequid Bay, and its numerous wide open side valleys, all of which are down to the base-level of erosion. One of the finest of these old eroded, sea-filled river-valleys is in New Brunswick, the Baie des Chaleurs, with its broad-valleyed backward extension, the Restigouche. (See Fig. 93).

DEPRESSION AND RE-ELEVATION. Sometimes a worn down region gets a new uplift; then the sluggish rivers regain a swifter current and begin to dig down deeper into their channels, which now get steeper and higher sides, and the former valley floor that was almost on a level with the water of the river, is now high above it, forming what is called "terraces" or "benches." (See Fig. 91.) Along the Restigouche and the Baie des Chaleurs, as along other rivers of this New Brunswick

region, these terraces are numerous, so that we must think this region has had, perhaps is having, an uplift again. And naturally, as the sea is in this bay now, we look in these old benches, or terraces, for shells of shell fish that belong to the sea; and such are found there; while farther up the Restigouche the shells are river-shells. But more than this: the old channel of the river that dug out the Baie des Chaleurs can be traced by the sounding-line far out into the Gulf of St. Lawrence, so that we know this region has to rise many hundred feet yet before it comes up to the old level it once occupied. By facts such as these, therefore, it can be told what changes of elevation a region has suffered.

In Ontario we have no such worn down mountains unless it be the Muskoka District and the rest of the Archæan region, and this has rather been a plateau than a mountain region.* Worn and polished and dug into by ice, with many of its water courses now long lines of lakes, some of them 400 feet deep (see frontispiece), blocked by the glacial drift, it still keeps, on the whole, the appearance that it bore before the ice covered it, and that was the result of untold ages of exposure to all the influences of the weather under very varied conditions of climate from tropical to frigid, and from moist to dry. For as we have seen (pages 17-19) this region, so far as is known, after having risen from the primeval sea, never wholly sank below it again.

The surface is rolling, its hills numerous and rounded, and from the top of the loftiest of them a tolerably even sky-line is seen, with a slight slope toward distant and lower country. What the appearance would be were all the Archæan rocks laid bare that are now covered by Palæozoïc strata to the south, it is hard to say; but along the edges where two kinds of rock meet, and where denudation has stripped off the far softer later ones, hills of the hard gneissic material standing above and out of the limestone around them, are quite common, and differ little in appearance from those that have never been covered at all.

The rivers of to-day, however, are all "young," for the blocking up or filling up of the old channels by the drift

*The Laurentides bordering the Ottawa on the north present exactly the same appearance as does the "South Mountain" as seen in Fig. 65.

material, and the gradual rise of the region again after its depression under its great burden of ice, have made the streams seek out new hollows that lead down to the sea or Great Lakes, and now they flow in narrow steep-sided rocky channels that sometimes may deserve the name of gorge, and their numerous little falls and rapids form those "portages" that test the endurance of the "canoeists" on the Moon and many another stream in this tourist's summer paradise,†

EXTENT OF DENUDATION. If the Archæan region is as old as has been said, and still remains so high, in many places over 1500 feet above the sea, the quantity of material that it has lost must have been very great, but how great is not known, perhaps can never be known. In younger mountain regions, all of whose strata can be traced, the extent of the loss by denudation may be pretty closely calculated. For when on a mountain side the worn off ends of the strata of which the mountain is composed are seen, and the thickness of each separate bed can be measured, the quantity of strata that has been removed can quite readily be told. Thus in the case of Pilot Mountain (Fig. 60) we can see by comparing its beds with the corresponding beds of the Fairholme Range (Fig. 63), that it has lost not only part of its present topmost bed but also one other whole bed; and perhaps two, for the Cretaceous to the left (Fig. 63) lies in its natural position on the older beds below it. In this way it has been calculated that the Uinta Mountains in the Great Salt Lake region have lost fully three miles and a half in perpendicular height; in the case of the Alps, Fig. 64, the loss must have been enormous also. Mt. Everest in the Himalayas is 29,000 feet high; how high would it be if all the material it has lost since it began to rise, could be restored to it again?

REMNANT MOUNTAINS.* At Montreal and in its neighbourhood there rise from the midst of the flat Quebec plain strangely isolated hills, or low mountains,—

† See an instructive paper by Alfred W. G. Wilson, Ph.D., of McGill University, in the "Transactions of the Canadian Institute," Aug. 1901, entitled "Physical Geology of Central Ontario."

* Many United States geographers call the larger of these "monadnocks," and the smaller ones "buttes;" when volcanic these latter are termed "volcanic necks," and the flat-topped ones "mesas."

Mount Royal, Mt. Johnson, the Belœil Mountains,—and others elsewhere; from a Canadian Pacific Railway train as it passes through the State of Maine, can be seen Mt. Katahdin rising in the dim distance solitary and alone; while in the Rocky Mountains "the Crow's Nest, (Fig. 67) standing alone amid lower hills, with bluntly conical top and bordered by almost vertical cliffs, is in its isolation a prominent object from the plains far out to the south-east."

Mt. Johnson, and the other Quebec mountains mentioned, though they have stratified rocks up their sides to some extent, are composed of hard volcanic trap which often shows itself in perpendicular precipices like those of Cape Blomidon (Fig. 25). And if they were once

Fig. 66. Mt. Johnson, near Montreal, a remnant volcanic mountain, or neck. Courtesy of Prof. F. Adams, McGill University.

volcanoes they must have poured out lava, ashes, and other volcanic matter not only on their sides and top, where the mass would be thickest, but over the whole surrounding country; yet no trace of these now exists, all has been removed from plain and flank and top alike, only the central part remains, the vent, from which the volcanic matter had poured forth, but now filled with the hardest of rock, the lava that had solidified in it. How much volcanic matter there was to remove, and how much of the stratified rock went with it, we do not know, perhaps never can know. Mt. Katahdin and Crow's Nest are not volcanic; their harder strata have kept them from wearing

away as fast as the other mountains around them, and now only a plain or "lower hills" remain where mountains once stood, for such mountains as these, whatever might have been the case with volcanic mountains, could never have risen from a plain leaving the plain still such, or broken only by low hills. Erosion and denudation have carried off the companion elevations, and these remain to tell what once was around them.

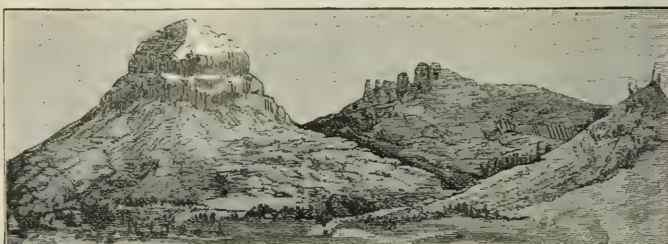

Fig. 67. Crow's Nest Mountain, about 4500 ft. high (7830 above sea level); 45 miles north of U.S. boundary line in southern Canadian Rocky Mountains. Top of mountain hard Devono-Carboniferous limestone; worn "chimney-like cliffs" of same in hill in background. Geological Survey of Canada.

But these remnants of higher ground are manifold in shape, from the sharp needle-like forms as seen in Figs. 63, 64, to the flat-topped table-mountain often acres or even miles in area, a huge level platform of lava-rock that has protected from erosion the softer strata over which the lava flowed.

VOLCANOES.

The terrible occurrences accompanying the outbreak of the volcanoes Mt. Pelée in Martinique, and Mt. Souffrière in St. Vincent, especially the former (in May, 1902) have made us all familiar with the nature of a volcanic eruption:—First the clouds of steam and other gases rising from the top of the mountain, the trembling of the earth, the loud noises like the discharge of artillery deep in the earth, the drying up of wells and streams, the vapor laden air; then the appalling explosion and rush, from the top and openings in the sides, of a vast column of steam often

miles into the air, mingled with a discharge of fragments of rock large and small and a cloud of finest dust,—rock literally blown to atoms,—producing total darkness, while torrents of water and mud, followed by streams of melted rock or lava, roll down the sides destroying everything in their path; and to complete the dreadful scene, if the volcano is near the sea, the water draws back from the shore for a few moments and then returns in a huge wave carrying destruction with it. The most terrible wave of this kind on record occurred at the eruption of Mt. Krakatoa in 1883, when a wall of water a hundred feet high rushed on the shore and miles inland in a populous region. Of the 30,000 or more people who perished during this great catastrophe, all except a few hundreds were the victims of the wave.

FORMING A VOLCANO. On Sept. 29, 1538, after two years of frequent earthquakes the old volcanic plain bordering on the Bay of Baiæ in the Bay of Naples, was suddenly burst open, and so great a quantity of mud and stones and pumice-stone was poured out that, in less than twenty-four hours, a great cone 440 feet high and over a mile and a half in circumference at the base was built up around the opening by the falling material. No lava flowed out but only large lumps of it were hurled high into the air. This was an entirely new, an infant, volcano, and now bears the name of Monte Nuovo (New Mountain). The opening or vent,—the *crater* as it is named, from its resemblance to the flaring sides of a cup,—though choked up by the stones, etc., that fell back into it, is still 421 feet deep. (Fig. 70).

All volcanoes were undoubtedly formed in the same way, but unlike Monte Nuovo, not all remained quiet after they were formed; they have burst out again and again, and the cone-shaped mass has become bigger and bigger through the repeated flows of lava and the showers of stones, ashes and dust, till it towers, as does Cotapaxi, thousands of feet above the sea.

But the regular cone-shape is seldom preserved; for the lava commonly stays in the crater partly filling it, and so becomes, on cooling, very hard rock; and when a new

eruption comes it cannot easily blow out this old plug and the fearful explosion that follows a successful effort will often break one side of the crater and the mud or lava will pour down the mountain through the breach so made; or a new vent or great cracks, or fissures, will open on the sides of the mountain and the lava and other matter will pour through these; and thus the cone-shape of the volcano will often be almost lost and a huge mass, such as Mt. Ætna in Sicily, will be the result.

THE CRATER. The crater, which may be of any width from a few hundred feet to two or three miles, remains filled with lava to a greater or less extent after the eruption is over, unless, as in the case of Monte Nuovo,

Fig. 68. Mt. Pelée, Island of Martinique, showing the crater-walls breached and old lava-flow to the sea. In eruption in May and September, 1902; crater reported to be much altered by explosions. From a drawing.

there is no lava. The lava in the course of time hardens over into a stony floor for the crater, but one or more vents remain through which steam, gases, and other matter, escape, and around which little cones are built up, often very fantastic in form, from the jets or spurts of lava thrown out by the escaping gases. So, too, when during an eruption new vents are opened either in the sides of the mountain or in the floor of the old crater, new cones will be built up around them. Ætna has two hundred of these on its sides, some being four hundred feet high. The present Mount Vesuvius is a new cone built up inside of

the old crater that was blown out in the fearful eruption of A.D. 79 when Pompeii and Herculaneum were buried beneath mud and ashes.

Curiously enough the floor of a crater whose sides have not been blown out, quite frequently becomes the bed of a lake the water of which in some is cold and in others hot, the latter being the case with the lake in the crater of Souffrière. Of course when the water is hot either it comes from far down in the earth, or the rocks remain hot not far below it. In the latter case the volcano is only dormant, or *sleeping*, and a new eruption may come at any time.

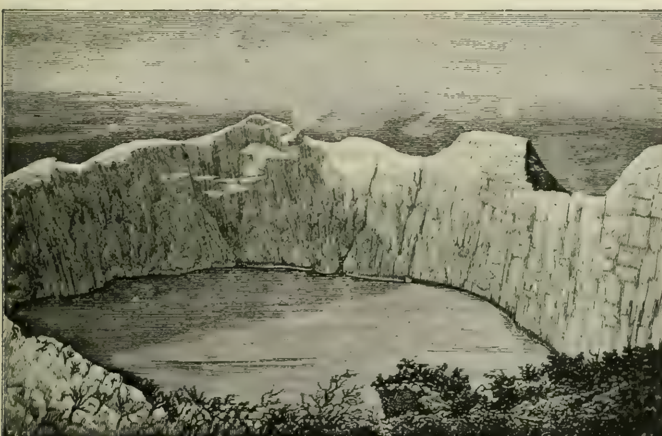

Fig. 69. Crater, with lake, of the Souffrière, Island of St. Vincent, one of the most remarkable in the world; three miles in circumference, over one mile across, minimum height of crater walls, 1000 feet. Lake reported to be destroyed and crater greatly enlarged by eruptions in May and September, 1902.

From a drawing.

ACTIVITY OF VOLCANOES. Volcanoes are said to be *extinct* when they do not send out, and never have been known to send out, smoke or steam, though gases, especially carbon dioxide, may still flow from them in large quantities as is the case in south-central France; they are *dormant* when, though they send out smoke and steam and gases, they do so without any violent eruption; yet the fact that steam, smoke, &c., escape and that the water

which at times occupies the crater floor is hot, shows that there may be an outbreak at any time. But it is hard to say when a volcano is extinct or only dormant. Vesuvius, before the frightful outbreak of A.D. 79, might have been called extinct, no eruption ever having been known there; its crater-floor was covered with trees, and an army of escaped slaves on one occasion had made it their camping ground. It has had long periods of quiet since, the longest one, from A.D. 1500 to 1691, again covered the crater floor with trees; but since the outburst in the last mentioned year, the worst by far since A.D. 79, Vesuvius may be called an *active* volcano. An almost similar story might be told of many other mountains, Krakatoa, for instance, or even Mt. Pelée. Souffrière contained the hot crater-lake, which gave warning of what might be expected at any moment.

Continuously active volcanoes are rare; Stromboli in one of the Lipari Islands near Italy is one of the best examples. At night the clouds above it are always aglow, and steam and smoke with jets of lava are continually being thrown out. But Mauna Loa in Hawaii, one of the Sandwich Islands, is the most remarkable of all the active volcanoes. The mountain in reality forms the island,—nearly a hundred miles in breadth and rising to a height of nearly 14,000 feet, out of a sea of still greater depth:—an enormous volcano. On its top, which is nearly level, is the crater of Mauna Loa, a gulf a thousand feet deep and between two and three miles across, in whose floor is a lake of lava in continual commotion through the uprush of escaping gases, the lava darting up in jets and columns and often cooling into most fantastic forms; but what is remarkable, with no steam accompanying it. On the side of Mauna Loa, but 10,000 feet lower down, and twenty miles away, is Kilauea, a similar and even larger gulf. Its floor is most treacherous. Its great boiling lava-cauldron seems to be surrounded by firm though hot ground, over which people tread to see the wonders of the awful place, but which is liable at any moment to break and sink, nearly the whole floor becoming a sea of fire with surging waves that dash against the walls of the crater and send the fiery spray hundreds of feet in air.*

* See Mrs. (Lady) Brassey's "Voyage of the Sunbeam" for a vivid picture of a descent into the crater of Kilauea.

At times the crater of Mauna Loa fills nearly to the top and then the molten mass from some unknown cause sinks again; sometimes, however, it overflows, but with no explosions as is usual in other volcanoes. In 1868 a vast stream poured over the crater's lip, and rolling slowly down the mountain side, sometimes plunging out of sight as it found great caverns or subterranean passages left by the shrinking lava of other days, then bursting up again and dividing for a time into two or more streams that enclosed stretches of ground like islands, it flowed for over forty miles till it reached the sea, where with a deafening roar and amid a dense cloud of glassy lava-scales, it poured over the cliffs, a cataract of fire, killing the fish for many miles along the coast and extending the shore for over half a mile seaward.

VOLCANIC DISCHARGES. Vast quantities of *steam* are present at every volcanic eruption; it forms the great white column that shoots upward with deafening roar from the crater, often miles into the air, to return in torrents of black rain, and at night it reflects the glow of the lava-filled crater or the burning gases and seems itself a mass of fire. It issues in clouds from rents in the mountain and from lava streams, and continues to come from the cracks long after the surface of the lava has become hard. The terrible explosions that shake and rend the mountain are mainly its work as it forces its way up from beneath into the crater and the air. It is by far the most abundant of all the numerous vapors or gases that volcanoes throw out.

Of these *gases* the hydrochloric and sulphurous acid gases, which are among the first to issue forth, are most deadly in their effects on animal life. At the eruption of Mt. Pelée in the island of Martinique in May, 1902, the whole of the population of the town of St. Pierre, about 36,000, perished, not one escaping. The appearance of very many of the bodies showed that death had come suddenly and by suffocation, the hand in many instances still covering the mouth and nostrils; and the few survivors on board the only vessel that escaped from the harbor, had fled for breath to the most enclosed parts of the vessel where the deadly gases had penetrated least. Hydrogen, oxygen and nitrogen with many of their compounds, some of them highly inflammable, are also present in large quantities; it is especially the burning hydrogen which causes the flames that form so grand a sight as they rise above the convulsed crater. Carbon dioxide, another deadly gas, issues from the crater after the eruption is over, and in many volcanic regions, ancient and modern, it continues to issue in large quantities from cracks and vents, although, as is the case with the mountains of Auvergne in France, no eruption has taken place in historical times.* The Valley of Death in Java, in which no animal

* So great quantities of gases are poured out in some volcanic regions that they form thick deposits on rocks, in fissures, and even on the open ground. It has lately been reported that the island of Volcano, one of the Lipari Islands north of Sicily,

can live, owes its character to the deadly carbon dioxide that issues from a volcanic rift in the rocks and fills the valley, and not to the Upas tree as was once believed. Enclosed valleys filled with this gas are not uncommon in volcanic regions the world over.

We have seen above and on pages 69, 70, that *dust*, or ashes, is poured forth in enormous quantities from every volcano whose eruptions are accompanied by explosions. The steam and other gases as they explode at the mouth of the funnel—the "pipe" that leads from the crater down into the earth,—blow the lava and even the sides of the crater and funnel into the finest of powder, and send it so high that the upper currents of the air catch it and carry it hundreds or thousands of miles away and even around the whole earth. The dust from Krakatoa rose seventeen miles in air, and produced total darkness for a hundred and fifty miles around, while in 1835 an eruption of Coseguina covered the whole region for thirty-five miles round with dust ten feet deep.

The explosions tear off from the sides of the crater and deep down in the funnel *fragments of rock* large and small and hurl them sometimes to great distances; Cotapaxi in South America is known to have hurled a distance of nine miles a block of stone weighing two hundred tons. Pumice stone, which is fragments of glassy lava blown into a mass of fine pores, as it were, is often thrown out in large quantities; one volcano in Japan over a hundred years ago threw out so much that it covered the sea for a distance of twenty-three miles and so deep that people could walk on it.

The *mud* that rolls down the sides of volcanoes, is in part poured from the crater itself, and in part consists of the dust that is gathered up by the water which comes from the sudden melting of ice and snow on the mountain side, or from the torrents of rain that fall from the cloud of steam over the mountain. It was this mud together with the sand and ashes, and not the lava, that overwhelmed Pompeii and Herculaneum in the fearful eruption of Vesuvius in A.D. 79, and that flowed down Mt. Pelée burying a large part of the town of St. Pierre in Martinique. So that it is no wonder that the remains of plants and animals buried by the torrent are often found wherever the mud, now hardened into a very soft crumbling kind of rock called "tufa," has been dug into.*

The water to form the mud that issues from the crater, must come in part from underground sources,—lakes, or streams, or reservoirs,—and in part from surface springs and streams that in some way are drained off into the funnel of the volcano, for it is not an uncommon thing to find large numbers of fish in the mud, some of them of a kind

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has been purchased by a commercial firm on account of the great deposits of pure sulphur, borax and other substances that are on it.

*Masses of this hardened mud at Pompeii and Herculaneum, known to contain human remains, have been carefully pierced and liquid plaster of paris or similar material poured into the cavity left by the decayed body; then when the liquid has hardened the stony case has been broken away and a "plaster cut" of the individual who had perished, often showing the very expression of the face, has been thus obtained.

belonging to the ordinary streams and lakes, but others blind, and with other peculiarities which show that they belong to underground waters.

The *lava*, which is so grand and terrible a feature in an eruption, though far less widely destructive than some of the other discharges, is to some extent melted rock, but mainly the uncooled liquid mass from the interior of the earth. Sometimes it swells up and fills the crater and then pours over its lip, sometimes it bursts the crater walls and rushes out through the breach, and sometimes it gushes out through so many fissures in the mountain side that the mountain seems "to sweat fire." Only at first, when it is most liquid and where the ground is steep, does it flow fast; on a moderate slope and before the top cools, it does not move faster than four or five miles an hour, though it has been known to go twice as fast. But the top soon cools into roughly square cakes or lumps, and then it moves very slowly and with a harsh, grinding, clinking sound. It may continue to move for weeks and even months, and often so slowly that the eye cannot detect any motion.

Strangely enough the seams or lines of separation (or union) between the floating cakes of lava are continued downward into the mass as it cools, and when the rocks are afterwards weathered or eroded, it is along these seams that the weathering and erosion cut deepest. Many of them, as the lava cools, draw apart, and in course of time are filled with various kinds of mineral matter dissolved from the rock by water, or deposited, especially if in the shape of crystals, by the mineral laden vapors that rise through them while the lava is cooling. It is these varied seams that give the peculiar and often fantastic shapes and markings to trap and other lava rocks along the sea shore. (See Figs. 121, 123).

Heat often continues a very long time in a thick lava stream, and steam rises from it as long as the heat remains.* Yet, strange to say, thick layers of ice and snow are occasionally seen lying beneath cold beds of lava, the heat not having been able to melt them. A lava field, ere time has clothed it with vegetation,—which with some lavas may be only a comparatively few years but with others not for centuries,—is a scene of the most utter and terrible desolation.

The amount of lava discharged is often prodigious, and was even greater in former ages than in modern times. The two greatest ancient (Tertiary) lava fields known are in Idaho and the surrounding regions, where the depth of the lava reaches in places 3700 feet, and in the Deccan in India, where, though the area covered, about 200,000 square miles, is much smaller than the one in the United States, the depth is greater, being fully 6000 feet. "The greatest outflow on record took place in 1783 in Iceland, when Skaptar-Jökull discharged from fissures, some of them twelve miles long, lava that filled up river gorges 600 feet deep and 200 broad, forming lakes from twelve to fifteen miles long and a hundred feet deep, and then stretching out into two great streams one forty-five and the other fifty miles long and a hundred feet deep." —(Geikie).

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*"Jorullo in Mexico sent out lava in 1759; twenty-one years later a cigar could be lighted at its fissures, . . . and after eighty-seven years of cooling two vapor columns were still rising from it."—Geikie.

EROSION OF VOLCANOES. The soft material that forms by far the greater bulk of a volcanic mountain,—the sand, and ashes, and mud (or tufa),—is very readily acted on by the rain and streams, so that the sides of the volcano are strongly marked with deep ravines separated by steep sharp-edged ridges, "looking like an umbrella half closed."

VOLCANIC REGIONS. Volcanoes have occurred all over the earth during some period of its history, for volcanic matter and volcanic mountains are met with everywhere. At present some three hundred active volcanoes are said to exist; fully half of these occur in the continental islands forming the East Indian Archipelago and the long line stretching up the western side of the Pacific from New Zealand to Bering Strait and indeed to Alaska; the most of the others occur in the western mountain region of America, the newer mountains of the world. There are many also in the West Indies and the Mediterranean, and some in the islands on the African side of the Atlantic and many in the oceanic islands of the tropical regions of the Pacific. Some few are found inland, as Mounts Kilimanjaro and Kenia in eastern Africa, Ararat in western Asia, and in central Asia, while the Arctic Ocean has Hecla, Skaptar-Jökull and others in Iceland, and the Antarctic has Mounts Erebus and Terror in its continent.

NEW VOLCANOES. Apart from shoals and temporary elevations formed in the sea by submarine eruptions very few volcanoes have been recorded as arising in historical times. In some parts of the western mountain region of the United States there are volcanic cones that have evidently been formed since Europeans came to America. One in northern California is a mile in circumference at its base and is over 600 feet high with a very deep crater: no trees grow on its sides or upon the rough field of lava that flowed from it; but the near-lying region, which is covered with volcanic ashes, has trees upon it showing a growth of about two hundred years. There are several of such cones, evidently of late origin, in and near the Phlagræan Fields,* a highly volcanic region around the Bay of Naples; but although in writings both

*It was in another "Phlagræan Fields" in southern Thrace that the earth-born giants fought with Jupiter for mastery ere mankind had appeared on the earth.

before and after the Christian era there are frequent allusions to earthquakes and volcanic outbursts, there is no statement made about the forming of new mountains.

In 1759 a new mountain, Jurullo, much larger than Monte Nuovo (whose birth is referred to on a previous page), was formed on the plateau of Mexico through a sudden outburst from amidst cultivated fields. Great quantities of lava, beside other material, were poured out which kept their heat for over forty years. These two, Monte Nuovo and Jurullo, are almost the only volcanoes that are recorded to have been formed in historic times.

Fig. 70. Monte Nuovo, showing mouth of crater.

SUB-MARINE VOLCANOES. The very numerous volcanic islands with extinct, dormant, or active volcanoes rising from oceanic waters far away from other land,* must have had their origin beneath the sea, the volcanoes having burst through the ocean floor and gradually, through repeated eruptions, built themselves up above the water, for on all sides of the islands the water rapidly deepens to an oceanic character. Many sub-marine eruptions have been recorded as occurring around Hawaii, Iceland, in the Mediterranean and elsewhere, jets of inky water, columns of steam, stones and pumice being thrown out, a shoal remaining after the eruption was over. In 1821 a new island was discovered by an English man-of-war between Sicily and Africa and taken possession of; but when a few weeks later a governor and other officials arrived on the spot, no island could be found, but the sea was widely covered with pumice and other volcanic products. The sea in the meantime had washed away the supposed island, which had consisted only of these light volcanic materials and could not resist the force of the waves. But the water is now only a few fathoms deep over the spot.

*St. Paul's Island in the South Pacific is 2000 miles from land. It rises just above the sea; one side of the crater is broken down, letting in the sea, and so the crater forms a little bay.

FOSSIL VOLCANOES. Strange as it may seem it is the volcanoes of former geologic ages and periods,—for volcanoes have existed from primæval times—that reveal to us what we know of the internal structure of these mountains. The ground on which volcanoes rose sometimes sank again beneath the sea carrying the volcanoes with it, and new strata were formed over all, all to be once again lifted to the air; and some volcanoes have been completely buried and lost to sight beneath the mass of matter discharged from others. Both of these have been brought to light again by the same cause that shows us the interior of a plateau,—running water. The streams in the course of time have, some of them, cut their downward way through these old hidden fossil volcanoes and have thus given us a "section" of them, showing that

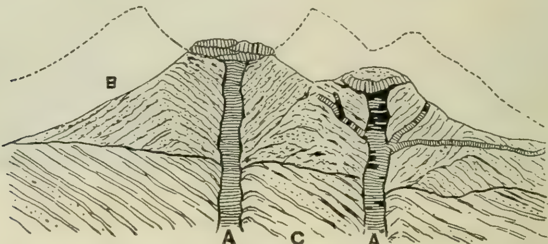

Fig. 71. Diagram of fossil volcano (Scotland). C, the strata pierced by the funnels A leading down into the earth one of which shows dykes parting from it; B, the cone of volcanic material; the dotted lines show the original height of volcanoes, the flattened tops of the funnels, or pipes, being the lava floor of the craters.

the hole, or vent, at the bottom of the crater in our modern volcanoes, which we can see, is only the top of a pipe, or funnel, that leads downward to an unknown depth into the earth; that the dykes which appear at the surface are cracks or rents far down into the heart of the mountain, through which the molten lava had been poured out and which like the funnel had remained filled with lava after the eruption; and how the mountain has been built up layer over layer of dust, sand, mud, rock fragments, and lava, the layers of dust and tufa still holding in them erect fossil trees whose roots are still seen buried in the fossil soil—which shows that in olden times as now volca-

noes had long periods of repose during which the surface of their barren rocky sides had decayed into soil and supported a luxuriant forest growth. Such fossil volcanoes are found in many regions, one of the most striking being seen in the walls of the deep cañon of the Snake River in Idaho, U.S.

VOLCANIC REMAINS. In Canada there are no volcanoes, active or dormant, unless some of the latter may exist undiscovered in the western mountain region; some extinct ones are known to exist there, but the region is not yet fully explored. We have only remnants of the volcanic action of by-gone geological periods and ages.

The dykes that are so common everywhere in the Archæan region, are volcanic in some form (Figs. 6, 11), and the great masses of granite that occur in the same region and especially near Lake Superior, and in Nova Scotia are volcanic too. Possibly these dykes, especially the larger ones, as seen in Fig. 11, are the filled-up fissures through which in remote geologic ages the molten matter was poured out over ground that now has been denuded thousands of feet, leaving the dykes and the worn-down rocks to tell the story of what once was. Then there are the beds of real lava, the trap rock, which are found in the western mountain region, near Crow's Nest for instance, and spread out many square miles in area, and deeply trenched by old river beds, on the central plateau of British Columbia; the same rock stands out boldly in Thunder Cape on Lake Superior, and forms the long ridge that bounds the whole of the southern shore of the Bay of Fundy in Nova Scotia, a ridge a hundred miles long and four broad, rising in its eastern end in the lofty bluff of Cape Blomidon (Fig. 25) and sinking into low, sheer sea-cliffs in Briar Island at its western extremity. Beneath the water of the Bay at varying distances from the shore soundings reveal three other ridges, trap too, for at each end of the Bay rises from them a volcanic trap island, Grand Manan, thirty miles long at the mouth, and Isle au Haut, only a few acres in size, near the head, both bordered with sheer and lofty cliffs.

Finally there are the worn remnants of individual volcanoes,—"volcanic necks," the lava that when liquid filled the funnel of the volcano and hardened there into

firm rock. Denudation has removed all the ejected material and left standing above the surrounding country these masses of hardest rock. Montreal Mountain, Mt. Johnson, Belœil Mountains and others rising from the Quebec plain (referred to elsewhere) are necks, others in the western mountan region are so like columns that they are sometimes called "plugs"—as if they were the very stoppers of the old volcanic funnels.

Fig. 72. Skoatl Point, Kuk-waus Plateau north of Kamloops, British Columbia; a volcanic plug; lava removed by denudation, showing old surface of plateau.
Geological Survey of Canada.

CAUSES OF VOLCANOES. The cause of volcanic action is not fully understood. Some men of science think from the fact that there is so much steam present in an eruption, and that volcanoes are situated close to the sea, that steam, or vapor of water, is the cause. The water penetrates the crust of the earth till it reaches the heated interior where it becomes converted into highly heated steam, and when the quantity becomes so great that the rock above cannot resist its expansive power, the rock bursts open, and steam, gases, shattered rock, and lava from the interior, rush forth. But it is objected that water, which might work its way very slowly downward, would be all turned to steam long before it reached the molten interior of the earth: and that though the greater part of volcanoes are near the sea, others are far from it.

Another theory connects volcanoes with the settling down of the earth's crust upon the molten mass beneath it.

(See Elevation of Strata, page 9 &c.) The crust in settling down, by its pressure upon the molten mass, forces some of it up to the surface of the earth through the breaks in the rocks made by the settling; and though the great lines of breakage are naturally near the sea, (since it is the vast beds of sediment which gather in the coast waters that cause the settling and breaking and so produce the mountains), yet the breaking may occur anywhere, and so volcanoes may occur away from the sea as well as near it, the greater number by far naturally being where the breakage usually takes place. According to this theory the lava poured out on the surface of the earth or forced into fissures and cavities beneath the surface, would tell us how much the earth contracts from time to time,—a statement not accepted by all.

A third theory is a modification of this one. It says that though some of the lava may come from the cause given above, yet most, if not all, is the result of the melting of the rocks, caused by the intense heat produced by the friction of the rocks as they settle down, or by the sudden giving way of the rocks during enormous pressure. For pressure, whether only for an instant as when a maul strikes a wedge, or long continued, produces heat, but the heat is not evident till the pressure is relieved. The pressure exerted by the rocks of the earth's crust against one another sidewise, caused by gravity, is inconceivably great; when the strain becomes too great for the rock to stand, a break occurs, the pressure is relieved, intense heat is developed, and the rock instantly melts, while steam and other vapors and gases, which are at the same time formed, force their way up through the fissure by their power of expansion, shattering the rock in their progress, and carrying along with them both the molten matter of the interior and the molten rock, saturating them at the same time, and finally exploding (or expanding instantaneously) in the upper air.

GEYSERS. Geysers (i.e. *gushers)* are springs that from time to time throw up columns of hot water and steam, and are found only in regions of volcanic action. Like volcanoes, they have a crater or basin on the top of a little conical hill, from which a pipe or funnel leads down

into the earth. Both pipe and basin are filled with beautifully clear boiling water. At regular intervals, usually, loud noises come from the ground, the water boils violently, and then a column of water and steam spouts up, sometimes over a hundred feet high, followed by a rush of steam alone equally high ; then all is quiet again. Geysers are caused by water filtering down through the ground and coming in contact with heated matter, when it is turned into steam, and after accumulating till its pressure becomes too great to be overcome by the weight of the column of water in the pipe above it, forces the water out of the pipe and thus makes a free passage up for itself.

Fig. 73. Crater of the Great Geyser in Iceland.

The crater is lined with a beautiful deposit of silica, coming from the waters, commonly of a pinkish hue but intermingled with rainbow colors. When several geysers occur on a hill-side, the whole hill becomes terraced with this beautiful deposit. The most famous of such terraces were in New Zealand, but they were destroyed some years ago by a volcanic eruption. In Yellowstone Park, Wyoming, where geysers are the most numerous, and

where perhaps the largest ones are, the crater is often a round vent in the top of a little mound shaped much like the old conical straw beehive, and are hence called "beehive geysers." Till the geysers of New Zealand and of Yellowstone Park were discovered, those of Iceland in the neighborhood of Mt. Hecla were by far the most famous, especially the Great Geyser and the Strokkr.

EARTHQUAKES. The cause of earthquakes is regarded by most men of science to be the same as that of volcanoes—the breaking and settling down of the earth's crust. For though earthquakes may occur and do occur everywhere on the earth without volcanic eruptions, yet it is in volcanic regions that they occur most frequently, and great volcanic outbursts are often preceded for months, or, in one known case, at least, for two years, by severe earthquake shocks. The West Indies, the Mediterranean, the East Indian Archipelago, the continental islands of Asia, all have frequent earthquakes, Japan seldom having a day without one, and the western side of America has very many more than the eastern; especially is this true of South America where so many disastrous earthquakes have occurred; and all these places are more or less volcanic.

Earthquakes are of all degrees of violence, from a scarcely noticed tremor such alone as, fortunately, we have in Canada, to shocks that throw down the most solidly built structures. The slighter movements are thought to be due to local displacements of rock usually not far from the surface, arising from various causes, such as the falling in of large caverns that underground streams have worn out, the settling of large masses into positions they had not quite reached on some preceding occasion, or the falling of near lying masses of rock into the hollows formed by volcanic explosions or the melting of the rocks by the lava in its upward progress.

EFFECTS OF EARTHQUAKES. Although the shocks of an earthquake do not last more than a few seconds, the effects are manifold. Loose objects are suddenly tossed up into the air, and trees, roots and all are hurled upwards; sometimes the ground seems to be thrown into a multitude of waves, or convulsions, that jar and shake objects back and forth, shift the blocks of stone in pillars

and monuments, break trees and topple down even the strongest of buildings,—the last a circumstance that has taught people in earthquake-afflicted regions to build their houses low and of wood, which will stand unharmed a shaking that would destroy tall, stiff structures of stone or brick. Springs and lakes are destroyed by rents that open new underground channels for their water, and new lakes and springs are formed by the closing up of old channels; great masses of earth or rock are loosened by the shaking from their places on hill or mountain-side, and fissures, even in the solid rock, suddenly open, sometimes remaining so but usually closing again,—as was the case in the awful earthquake at Lisbon in 1755, when as a multitude

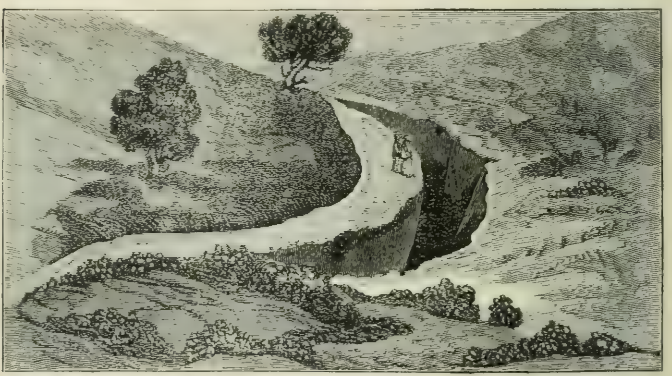

Fig. 74. Chasm in southern Italy caused by an earthquake in 1783.

of people, surrounded on all sides by falling buildings, were praying in the public square, the ground suddenly gaped beneath them, closing again almost instantly upon fully 60,000 victims.

The ground, too, suddenly sinks in some places and rises in others. The coast of Chili was permanently raised in 1822, and again in 1835, while a large district in India, near the Gulf of Cutch, comprising 2000 square miles was permanently sunk during an earthquake in 1819, carrying down with it a fort of the East India Company, the top of whose ruined walls still rises above the water. Even

in Canada we have had touches of effects like these. A few years ago at St. John after a slight shock of an earthquake, it was found that in one place the bottom of the harbour had sunk many feet, and a large hollow had been formed on some high ground two or three miles away.

This latter is a common effect of volcano earthquakes. In the harbour of St. Pierre in Martinique, where before the eruption of Mt. Pelée anchorage was everywhere found, now, it is reported, there is no anchorage; the bottom seems to have dropped out of the harbour.

When the shock of an earthquake occurs under the water but not far from shore, a great wave is raised which rushes on shore with frightfully destructive rapidity, so that often the wave does infinitely more damage than the shaking or subsiding of the land. Such a wave accompanied the earthquake at Lisbon, and the eruption of Mt. Krakatoa in 1883. Japan has such earthquake waves with terrible frequency, for, strange to say, Japan's earthquakes all come from under the sea.

EARTHQUAKE ACTION.

It has been ascertained that however much buildings and trees and even hills may shake during an earthquake, the mass of the ground moves only slightly; it is the suddenness of the jar, or rather of the succession of jars, caused by the settling down of the earth's breaking strata, together with their enormous weight, that causes such dire effects at the surface, for the distance that the great body of the crust falls at any one time is only very slight, even imperceptible, although in places here and there it may be many feet.

Examples of the effects of sudden action are very common. A slight blow of a hammer will drive a nail, while an equal amount of force exerted in pressure will have no effect on it; a stroke of a hand on a tree will jar it to the top, when a push with all one's strength will not stir it. A train of cars passing along a track (which may be regarded as a succession of sudden blows) over somewhat spongy ground, will cause buildings many hundred feet away to rock very unpleasantly.

Then, too, if we stand a few small objects, say pieces of lead pencil two or three inches long, some distance apart upon a table with a solid hard-wood top, and with a hammer tap the under side of the table beneath one of the pieces, the piece will spring into the air and drop back into the same place, while the others will also spring

up but not so high and will move away a little farther from the spot where the stroke was given ; should the first pencil just topple over as it comes down, the others will not do so but will only rock to and fro ; but if the stroke is sufficiently strong to cause all to topple over, the ones away from the stroke will all fall inwards,—as if they were suddenly pushed out at the bottom. If now a somewhat thick cloth be put on the table and the same experiments repeated, the stroke that caused all the pencils to topple over before would just shake them a little,—for the change from one substance to another, especially of a softer character, destroys much of the force of the blow.

These facts, especially the last, illustrate earthquake action. The places where the rock breaks, from which the jar or motion starts,—or the "focus" of the earthquake,—is down deep in the earth. The motion will reach the surface first right over the focus and then later and later the places farther and farther away from this spot; and in going these longer distances more and more of the force will be lost till at last it will be all spent.

Now it is plain from the illustration that if during an earthquake objects on the ground in a certain region are seen to spring straight up into the air, and in other regions far away to fall over rather than spring up into the air, the centre of the earthquake must lie right below where the objects spring up. But it is by no means always easy to see just how things happen in an earthquake; the shocks come suddenly and are almost instantly over, while people are too much alarmed, or terrified, to notice anything accurately; so that there is always some uncertainty in fixing the exact place beneath which the shock started.

But although this place may be with a good deal of certainty determined, it will not tell us how far down in the earth the focus is. Other facts are needed for this. Walls, for instance, are very commonly found to be cracked, the main cracks running parallel to each other; now, cracks of this kind always run at right angles to the direction of the force, or motion, that makes them.

In the diagram, Fig. 75, let *ab* and *cd* represent cracks made in walls twenty miles apart; now if lines be drawn perpendicular to these cracks to represent the forces that made them, they will meet at the point *g* below the surface of the earth *ef*. It will be an easy little problem in mathematics, the distance between *e* and *f* being known, to find the perpendicular distance of the point *g* below the

surface of the earth at h. But here again, as before, it is not at all easy to get facts to make these calculations. And besides, the crust of the earth is not equally hard or solid all through; we know that the upper strata are of very many kinds; some hard, some soft; some coarse grained, some fine; there are beds of sand, and lakes and streams enclosed in the earth; and there are caves and faults, and contorted and broken strata—in short all kinds of things that will hinder or turn aside the direction of motion, or like the table-cover in the experiment with the hammer and pencils, greatly weaken the motion. And so all that can be done is to determine *about* how far down in the earth the rocks gave way.

Thus the focus of the earthquake in southern Italy in 1857 was about five miles deep; that of another in central

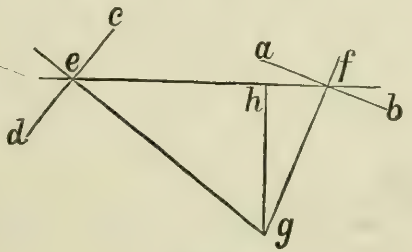

FIG. 75.

Europe in 1877 was about fourteen miles deep, while that of the earthquake at Charleston, South Carolina, in 1886, was nearly twelve miles deep. It is thought no earthquake centre is more than thirty miles deep.

EXTENT OF SHOCK. The rapidity with which a shock travels varies very much: it seems to depend upon the distance from the centre and the force of the shock at first. With some earthquakes the rate of motion has been only about 300 feet a second, while with others it has been over 9000.

The size of the region affected by a single earthquake varies very much also; sometimes it is only small as in the case of volcanic earthquakes, or where the shock is feeble at first, or when the centre is near the surface; for in this last the loose or disordered strata through which alone the jar has to pass, soon destroy both force and motion, though the shock may be very violent directly over the centre. But when the centre is deep-seated and the original force great, the effect is felt over

a wide area. The earthquake of Lisbon in 1755 was felt from Norway to Africa and across the Atlantic to America, and that of Charleston in 1886 was felt from some distance west of the Mississippi out to the Bermudas, and from the Great Lakes and the St. Lawrence to the Gulf of Mexico and Cuba.

Of course a shock from a very deep-lying centre will do less harm on the surface of the ground than one of equal force from a centre higher up.

17. PLAINS AND PLATEAUS.

The terms "plain" and "plateau" refer in part to the character of the surface of the land and in part to elevation above the sea. In both plains and plateaus the ground may be flat or somewhat sloping and uneven; mountains, too, may rise from them. Generally, expanses of land whose upward slope does not reach an elevation of more than a thousand feet are regarded as plains; beyond that height they ~~are~~ usually called plateaus. But it is quite evident that no distinct line of separation can be made between the two;—one passes gradually into the other. In the great plains of the Canadian West the slope in many places is not perceived by the traveller, though the rise from the Red River to the Rocky Mountains, 750 miles, is over three thousand feet.

PLAINS. Plains form a large portion of the land surface of the world. One immense plain stretches along the northern part of the Europe-Asia continent from Bering Strait to the Atlantic, including in Asia all north of the Altai Mountains, in Europe all Russia from the Arctic Ocean to the Black Sea,—sinking to eighty-five feet below sea-level at the surface of the Caspian,—all northern Germany and western Europe, with northern France and parts of the British Islands; in Australia, all except the low eastern mountain region is a plain; in North America, all from the Gulf of Mexico to the Arctic Ocean, between the mountains east and west, together with a narrow fringe along the south-east Atlantic coast; and in South America, all the east and central part except the mountain block of south-eastern Brazil. Africa, strange to say, has none except in the north-east, and here there are some spots below sea-level; the continent is one great, though not high, plateau.

COASTAL PLAINS. Existing plains owe their many differences in form and character to their origin and age. When, after a long period of rest during which the rivers and currents have been busy carrying down and spreading out beneath the coast-waters sediment from the existing land, upheaval again begins, the result will be a level, flat expanse extending from the older and higher ground out to the sea, and covered with the loose material of the sea-floor,—sand, fine and coarse, and clay; there will be no rock within many feet of the surface. The rivers crossing it from the old land will have a slow current, for the slope will be only slight, and they will tend to wind very much and to become wide but not very deep; the slowness of the current, of course, permitting them to be navigated. New streams will of necessity be formed, for the slight slope of the new land will be as yet only seaward; but these will be sluggish, and there will be much low swampy ground that has no drainage. Such a plain as this —a Coastal Plain—extends from New York Bay down the Atlantic coast and around the whole border of the Gulf of Mexico. Such a plain, too, but of far greater extent, is the northern part of the great Europe-Asiatic plain,—that dreary region of moss, willow and alder, and soil perpetually frozen except for the few inches at the top that the sun of the short summer can thaw—the Tundras. In Ontario the flat low-lying strip of land that extends back from the edge of Lake Ontario to the escarpment, a mile or more away, is a real lake-coastal plain; and in old Devonian days the Cambrian and Silurian strata that now form so much of the Province, lay as a coastal plain to the old Archæan shore behind, while the Devonian strata were being laid down beneath the sea in front.

Along the western coast of North and South America, especially of the latter, where the mountains skirt the sea, narrow coastal plains exist, but they are rather the waste from the mountains than a newly elevated sea-floor, except where in very many cases volcanic action or earthquakes have produced them.

PLAINS OF SUBSIDENCE. The low-lying plain skirting the St. Lawrence in Quebec and Eastern Ontario, and extending as a border several miles wide up the southern side of the Ottawa nearly to Ottawa, has many of the characteristics of a coastal plain,—a flat monotonous surface, sluggish shallow winding streams and numerous bogs and depressions. The streams, however, of any size show rock, often indeed flow over a rocky bed, and nowhere is the rock very far from the surface. The beds are nearly horizontal and show great denudation. The great glacier moved over it, and the material now on the old ice-rubbed floor is glacial in part and in part a sea deposit. For a depression came after the glacier had gone and the whole

Fig. 76. Plain in north-west of Prescott Co., eastern Ontario; Laurentide hills about ten miles distant. View looking north from top of hotel at Caledonia Springs.

region was again an arm of the sea, to be raised to land once more when this, the Champlain era, had passed away.

PLAINS OF EROSION.* Still other plains have other characteristic marks. They may come down to the sea as they do in the Maritime Provinces and the New England States, or they may be far inland. These are not flat but are roughened by high, sometimes rocky, hills and deep hollows. The rivers do not meander in curves and loops, and their sides and beds often show rock, while the current

*Some writers in the United States suggest the name "peneplain" (almost a plain) for these plains.

is strong, and if they enter a low flat plain rapids or waterfalls mark the place of change. These are all much older than the coastal plains, and owe their peculiarities to long exposure to the agents of denudation. Such plains as these, some of them, were once mountain regions, for the underlying rocks, where they are exposed in river-banks or in excavations, show foldings and contortions (Fig. 18) which do not exist where the strata have been only slightly elevated. Some low tracts of the Appalachian region both in the United States and in Canada are plains of this kind. But the Carboniferous region of eastern New Brunswick and Nova Scotia, and the red-sandstone (Triassic) Prince Edward Island, where the strata are not disturbed, were probably never very high although their present low-lying conditiou

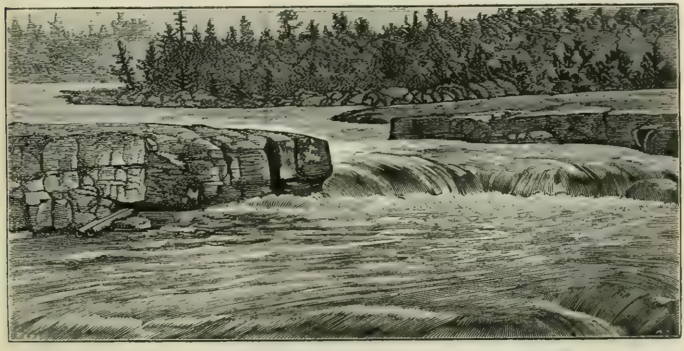

Fig. 77. Pabineau Falls, near Bathurst, N.B. Strata horizontal; fall, low; elevation of country very moderate. (Official).

is due, as we have seen, to subsidence as well as to denudation by weathering and glacial action.

The part of Ontario lying outside the Archæan region, although its roughnesses are due mainly to the glacial drift, may be regarded as such a plain also. It is higher than either eastern New Brunswick or Prince Edward Island, and is older than either. The rapids of the St. Lawrence and the Falls of Niagara show plainly, too, that it is higher above the sea than Quebec is. But the most remarkable feature of the Ontario plain is that its central part is much

lower than the parts east and west. On the west there is a line of limestone escarpment that, crossing from New York into Ontario at Queenston, runs west to Hamilton at a little distance from the Lake, and then sweeping round runs north to Collingwood and beyond, while on the east a similar line, starting from a little east of Kingston, runs almost directly west to the Severn, north of Orillia. Streams from the higher ground enter the lowland through gaps that they have cut in the escarpment (Fig. 85); some of the gaps, especially in the west, are narrow short gorges with almost perpendicular sides, the streams not being graded down to the bottom of the escarpment (see Fig. 47); while others have a width of many miles and run back for nearly twenty

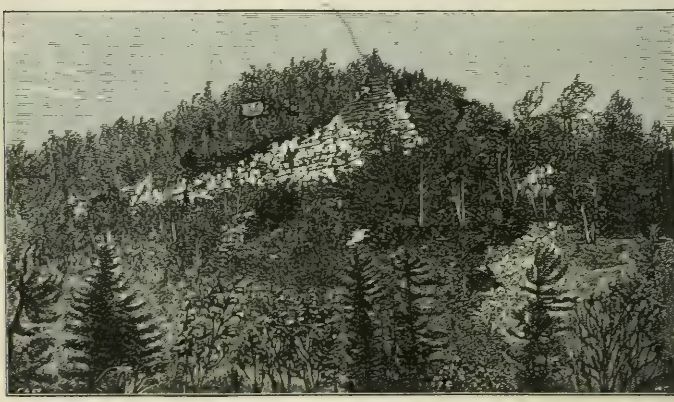

Fig. 78. "The Peak" Niagara escarpment at Grimsby; trend of main escarpment, to right; trend to left is the top edge of the ravine cut by stream (Fig. 47). Phot. taken from talus slope of escarpment across ravine. See also Fig. 41 and 85.

miles. So wide and deeply excavated are these that they are thought to be, in a large degree, the work of rivers that existed before the glacial times, the Dundas valley being specially remarkable. (See page 143).

The drift of the glacial era lies everywhere over the Ontario plain; it is thin in the south east where for miles along the railway routes the bare limestone rock is visible; while to the west it is everywhere spread out deeply though

irregularly. A broad line of old moraines* extends from Trenton directly west to the Niagara escarpment, and beyond into Wellington and Waterloo counties markedly roughening the surface, and often standing out as high hills such as those along the Grand River near Galt.

The flattest part of the Ontario plain is in the western counties,—it is almost absolutely flat, so flat that the natural streams cannot carry off the water, but artificial channels have to be dug at public expense to assist them. Here the Thames pursues a very winding course in a channel dug deep in the clayey soil but with such a slight fall, and such a sluggish current, that in spring time the

Fig. 79. Morainic ground, Bathurst, New Brunswick.
Geological Survey of Canada.

channel is full to the brim and the neighboring districts are often lying deep in water. The river is down to its base level with reference to Lake St. Clair into which it flows. There are some interruptions here to the general clayey and often swampy flatness, such as the fine rich agricultural ridge of drift in Kent county,—a ridge with a width of three miles or more lying a short distance back from Lake Erie and shutting off the Thames from its natural course from the high ground of Stratford and its neighborhood southward to the Lake.

THE WESTERN PLAINS. The great plains of western Canada, except the eastern division, are usually regarded as plateaus. The whole region rises with a gentle slope from the Red River, where it is about seven hundred feet above sea-level, to the Rocky Mountains, a distance

*These are to be seen along the line of the Canadian Pacific railway east of Toronto.

of seven hundred and fifty miles, where it is four thousand feet high,—an average of about four feet three inches in a mile. But the slope is not uniform; there are three successive stages in the rise,—"prairie steppes," as they have been called. The one on the east, the first and lowest, "the most absolutely level prairie region in America," extends, (with the width of about fifty miles at the international boundary), from Lake Winnipeg directly south across the border two hundred miles into the state of Minnesota,—a total length of three hundred and fifteen miles. The Red River runs sluggishly along the lowest level to Lake Winni-

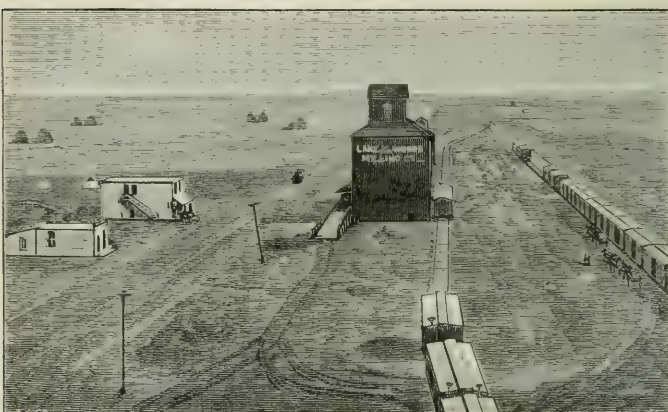

Fig. 80. "The most absolutely level prairie region in America."
(Official.)

peg but has not cut a deep channel, for it is down practically to its base-level of erosion, the hard ridge in its bed at Selkirk, which gives rise to a rapid, having checked its further downward progress; when therefore a sudden thaw in spring comes, the banks of the river cannot contain all the water, and so large sections of the country are flooded. Drainage in both country and city is a matter of difficulty. There are no stones in the region except a few lonely worn boulders here and there. The soil is of a very fine material and very deep, such as is known to be deposited in lakes and large ponds. The eastern boundary is in part the old

Archæan highland near Lake Winnipeg, and in part high hills of drift west and north of the Lake of the Woods. On the west the boundary is an escarpment, rising into the Pembina Mountain in southern Manitoba and appearing with terraces and low rocky cliffs at different points farther north, though in the most northerly part the escarpment can hardly be traced. The rocks of the escarpment are all waterworn (Fig. 34) ; this with the presence of terraces, the fine material of the soil, like the "silt" of lake bottoms, the gradual even slope from the head of the plain in Minnesota, 960 feet high, to Lake Winnipeg less that 260 feet lower, or about ten inches in a mile, and the gentle, and to the eye imperceptible, rise towards the sides,—all show

Fig. 81. On the Little Souris, S. Manitoba.
(Official.)

that this region, one of great fertility, was once the floor of a great lake. (See page 42).

The level, or "steppe," to the west, with an average height above the sea of about 1,600 feet, and with a breadth of 250 miles at the border, is very different from the one to the east. The surface is quite uneven and deeply covered with drift; in such quantities is the drift that Turtle Mountain, a broken hilly region about twenty miles square rising 500 feet above the plain, and others near it, are thought to be wholly of drift; boulders, chiefly of Laurentian rock, are plentifully scattered over the surface; the slope, though slight, is perceptible; the rivers have more current and lie in broad flat-bottomed valleys between

banks sometimes three hundred feet high. The rivers are not large, but they wind across the valley from one side to the other in a truly serpent shape. All appearances show that this region has been much longer exposed to the action of denuding and eroding agents than the one to the east.

The third level, or "steppe," is about 450 miles wide at the border, and slopes upwards within this distance from a height of about 2000 feet above the sea at its eastern side to 4200 feet at the foot-hills of the Rocky Mountains. But it is quite a different region from the last one. Drift covers it, but to a far less extent than it does the second level, and rocks are seen along the river banks not far below the surface. Unlike the drift of the second level, which is mainly from the underlying rock, the drift here is for the most part, and wholly so near the mountains, a form of quartz, and has undoubtedly come from the Rocky Mountains region. The boulders are mainly the Laurentian gneiss and granite, and have travelled at least 700 miles hither. The rivers are numerous and of considerable size, and though lying in even deeper valleys and "couleés" than those of the second level, they are still at work digging them deeper. The central part is an almost flat-topped plateau, which forms the divide between the rivers flowing north-east, and those flowing southerly to the Missouri. But the most remarkable feature is the boundary region, called the "Missouri Coteau," between this and the second level. It is a region of abruptly rounded and "tumultuous hills" from thirty to forty miles wide. "The hills are entirely of drift material, many of them seem to be formed almost altogether of boulders and gravel." There are no river courses among the hills, but the rain, after washing down the finer material to the hollows, settles there to form lakes; these dry up during the summer and leave the ground covered with sulphate of soda, magnesia and other salts. The great mass of drift has destroyed the river courses of pre-glacial times. This "Coteau" has a length of fully 800 miles in the United States and Canada, and is regarded by geologists of the United States as a huge terminal moraine of the great ice sheet. but by leading Canadian geologists as the work of floating ice which broke off from

the outer edge of the glacier that covered the Laurentian land in the east, and floated as huge icebergs laden with waste across the depressed sea-covered interior, and grounded here, melting and depositing their burden.*

PLATEAUS. Ideally, a plateau is an extensive elevation of land over 1000 feet above sea-level, with sides rising somewhat steeply from a plain below, and with a flat or nearly flat top; practically no such elevation exists or can exist, except in very limited area, for the upraising of a great mass of land would require very many thousands or even millions of years, and during all that time, from its very beginning, as we have seen, the denuding and

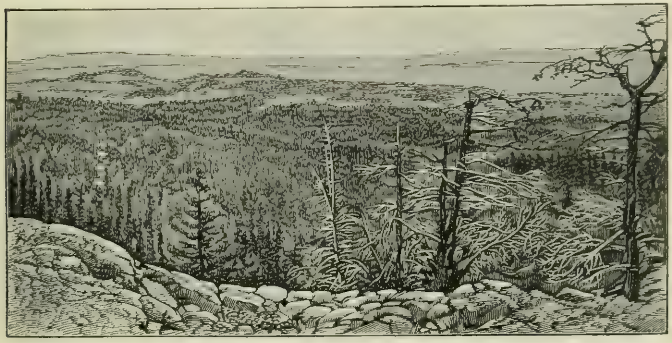

Fig. 82. Plateau in British Columbia, forest-clad, 4000 to 5000 feet high. View from Choo-Whels Mountain.

Geological Survey of Canada.

eroding forces of nature would be at work carving it into blocks of various sizes and shapes, and reducing the height of the blocks with various degrees of rapidity. Only in a climate where moisture is very deficient can there be an approach to this ideal plateau,—such as the Colorado River plateau of the south-west mountain region of the United States. Here the strata are hard and nearly horizontal, and as the district is almost rainless, any denudation by wind or chemical action must be horizontal too, so that the rivers, which have their starting point in distant snow-

* For pictorial illustrations of the second and third "steppe" see under "Economic Geography."

covered or rain-washed mountains, in flowing over this dry region on their way to lower ground, have cut only narrow channels in the rocks. In one place the bed of the Colorado lies over 6000 feet deep, and its walls are apparently, though not in reality, perpendicular. (Fig. 99.)

The interior of British Columbia is a plateau, but so roughened by long exposure to the unequal action of streams and weather that its real plateau character is to be perceived only by the fact that the tops of its highest elevations are on one general level. Here and there, however, are some comparatively level stretches of open grassy country. As in other places, notably in Oregon and in southern

Fig. 83. On a British Columbia plateau, Stump Lake; open grass country of lower valleys.

Geological Survey of Canada.

central India, many of the old roughnesses were filled up by vast outflows of lava in Tertiary days (Fig. 72); but the lava in its turn has been cut into so much and so deeply by the energetic action of the rivers that, though the glacial drift (which is found here too) has filled many of the old river channels and blocked up others, yet if the region should sink 3000 feet below its present level it would be only a mass of islands.

As has been said above, the western side of the great American plain, in the United States as well as in Canada, is a plateau in reality; so too is much of the western cordillera or mountain region though very greatly higher. Mexico, except a narrow strip along the Gulf, is wholly a

plateau, undulating for the most part. Some plateau regions rise from ten to twenty thousand feet in air, such as Thibet and Peru and Bolivia. In Europe many of the countries are plateaus in whole, as Spain, or in part, as France, Austria and Germany; while in Asia nearly the whole of the southern half, stretching from Arabia to Bering Strait, is plateau; Africa is almost wholly plateau.

Muskoka, together with the Archæan regions bordering Hudson Bay (see "Old Mountains"), is a plateau, but a very old one whose worn surface, never more than 1500 or 2000 feet above the sea even in Labrador, where it is highest, is the result of the work not alone of the great glacier, but also of the denuding agents of untold ages before the glacier appeared. For where along the outer rim of the Archæan area the old limestone rock (the Cambrian and Silurian) that was formed on it after it had sunk in part beneath the sea, has been worn away by weathering or otherwise, the old surface thus exposed, which had never been subjected to the action of ice, presents much the same appearance as does the ice-worn part that never sank.

Furthermore, borings have shown that at Toronto the old Archæan rock lies eleven hundred feet below the surface, though not so far at other points to the east, and it is found that the slope upward varies in different places from twenty feet to over forty in a mile. But the Muskoka region has little slope in comparison with this; we must therefore think that the old Archæan continent has been lowered,—not only by subsidence but also by a great denudation. So, though it has been re-elevated and exposed to the grinding of the glacier, and its old water courses have been filled by the drift waste, and new streams have been formed, and denudation has been going on since the glacier left, yet the story told by these borings and the old uncovered rocks, makes us certain that the flattened though rugged appearance of this old region to-day, is not unlike what it was ere the glacier came upon it,—what the work of the countless centuries of the Palæozoïc and Mesozoïc periods, and of the earlier ages of the Cainozoïc had made it. (See frontispiece.)

CHAPTER IV.

RIVERS AND RIVER VALLEYS.

Very varied are the sights that meet us as we pass up one of our rivers. We enter the St. Lawrence from the sea, and the river is so broad that one bank cannot be seen from the other; but as we go onward both banks appear, and two mountain ridges seem to be closing in on the river, one on each side. These disappear and above Quebec the river, broad but with very moderate current, flows between banks but little higher than the surface of the water and stretching away almost as far as the eye can reach, and nowhere along its whole length are anything but little unevennesses again seen; we pass through a broad expansion of the river, Lake St. Peter, and though there seems to be an abundance of water, the vessel takes a strangely crooked course

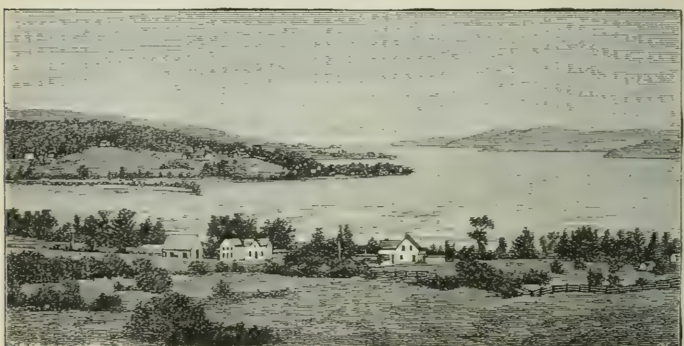

Fig. 84. Looking up Long Reach, St. John River; a straight stretch 18 miles long. (Official.)

through it, and we pass a dredge, more than one, at work digging up mud out of the bottom. At Montreal we enter a canal, for the Lachine Rapids prevent a vessel from sailing on the river here; we enter the river again into another lake-like expansion, and soon again into a canal, for there are more rapids; and this continues,—alternate rapids and reaches of smooth water but yet with a strong current,—till near Prescott, when the rapids disappear though the current remains; then passing through multitudinous islands we find ourselves, at Kingston, in Lake Ontario,—the first of a series of inland seas, connected with Lake Erie, the next one, by a short but strong stream that in its mid course

plunges over a precipice more than a hundred and sixty feet high, whence it rushes in one long rapid for half the distance to Lake Ontario through a gorge with perpendicular sides. Everywhere in the river the water is clear, except in Lake St. Louis; for there the Ottawa joins it, whose water is somewhat discolored.

Again, if we take a steamer at St. John and sail up the St. John River, features not met with on the St. Lawrence will be observed. The river is seen to lie in a deep valley from its very mouth, a valley that resembles a flaring **U**, approaching to flat for a short distance on each side of the stream in most places, notably between St. John and Fredericton, and then flaring upward into high somewhat rounded hills, with intervening but shallow valleys. The current is not very strong unless when the river is in flood; where side streams enter, such as the Jemseg, there are low flat islands just above the water, and similar islands occur along the course of the river from a few miles above St. John up to Fredericton; they are not rocky islands as are those in the St. Lawrence, but wholly of soft soil—river silt, or alluvium. The city of Fredericton stands on ground that is just like these islands, and back of it lie the old worn-down rounded hills, while beneath the surface-soil is sand such as is on the river-beach. Above this city hills still border the stream, which is now much smaller, till we suddenly find it issuing as a rapid from a long, deep, narrow gorge, at the upper end of which the river pours over a cliff—the Grand Falls.

In the North-West the Saskatchewan, Assiniboine, and scores of others flowing through an almost level region, lie anywhere in flat-bottomed valleys often over two miles wide, and bordered with steep banks sometimes nearly four hundred feet high, or wind in them in long lingering curves or loops from one side to the other. The Saguenay enters the St. Lawrence between rock-cliffs over a thousand feet high where the water is almost equally as deep. The Restigouche and many another in some part of their course spread out over a wide bed, become very shallow, and divide into several channels that reunite again; while round our Lower Lakes the numerous little streams discharge their water, for the most part, with a scarcely noticeable current, and wind lazily from side to side of a little flat-bottomed valley lying between steep banks that open broadly lakewards. These and many other phenomena, some seemingly strange, are met with not only along rivers of Canada but along rivers throughout the world. What is the cause of them?

RIVER WATER. We have seen in former pages how the beating of rain on the soil or the rocks tears off particles from them so numerous that the water of the rills which form on the hillsides during a storm, is dark and thick with the waste, and these muddy rills find their way into larger streams pouring into them not only their water but their load of waste, and thereby giving to these larger streams the means of wearing away, or eroding, the rock at the sides and bottom of the channel through which they flow.

But this land-waste, or sediment, is not the only means that the water possesses for eroding its rocky channel. The rain, we have seen too, gathers gases out of the air, and from decaying vegetable and animal matter, and these also pass into the rivers. So that the running water of rivers has three means by which it can wear away its bed and sides,—its own onward motion with which it strikes against and forces off particles of rock; the waste, fine and gritty, or coarse, which rubs away or grinds down the rock; and the various chemical elements which dissolve the material of the rocks and carry it off in various chemical compounds, the water remaining clear and pure to the eye.

ORIGIN OF RIVERS. It is quite plain that there can be no mountains without valleys; and valleys are for the most part the work of streams, while streams themselves are but so much of the rain that the ground does not soak up and retain, or that the sun's heat does not evaporate,—no matter whether we say the stream comes from a lake, a spring on hillside or in meadow, a bog or swamp or oozy ground, or the melting ice of the glacier.

We cannot tell how long the streams that we see about us have actually been in existence, except where, here and there, earthquakes, or some other cause, have interfered with the underground water-courses and caused new springs to burst forth. But the rocks beneath the streams will tell us something about their age. The Saskatchewan and the Red River run over rocks of a far later period than do the Grand, the St. Lawrence, or the St. John; yet in view of the great changes of the earth which a study of the rocks and of the earth's surface reveals, it would be unwise to say that these three last mentioned rivers are therefore older than the Red or the Saskatchewan; still we are warranted in saying that in all probability they are older, for while these two pass over Mesozoïc rocks, except in their extreme lower courses, and could not therefore have been in existence in Palæozoïc times, the others may have existed in Palæozoïc days, for they pass over Palæozoïc rocks which show no signs of having sunk again after having been once raised above water, or which, as is the case with the Lower St. Lawrence, after having sunk rose

once more, the river re-occupying its old channel; and the St. John undoubtedly had its origin far back in Palæozoïc days.

How rivers began on ground new-risen from the sea we can readily imagine from what we see taking place during a rain-storm on every freshly cut bank or newly ploughed field. We see the water that does not sink into the ground, gather into multitudes of little rills, some larger than others, which take their way directly down whatever slope there may be; and if the storm be violent and long-continued, and the field a large one, deep trenches may be dug and a stream continue to flow in them for some time after the storm is over.

The new-risen ground got its first streams from the first rain that fell on it; the little rills ran directly back to the sea and left behind them, when the storm was over, the channels they had made. Then as ages passed on and more land continued to rise from the sea, and what had formerly risen grew higher and higher, the streams would no longer dry up after a storm but continue to flow; for the rain that sank into the loose soil or the softer rocks, would come in contact with a bed of clay or of hard rock and reappear here and there at the surface of lower ground as springs; or little lakelets would gather in hollows and bogs, and swamps would grow up and store away the water,—to be given out again slowly and steadily; till at last with the increased extent of land and the multiplied natural reservoirs the streams would have a continuous flow however long the time between the storms.

GROWTH OF RIVERS. But while these primeval streams were becoming permanent in their flow, much more was going on. They were becoming longer. For the land as it grew higher and higher carried their starting points, or "sources," ever farther away from the shore; some of them at least would still occupy the channels, however much changed, that the earliest ones had dug in the little depressions along which they first ran to the sea, and would continually eat backward as the land rose higher, and extend their channels across the new land as it rose from the sea in their front. Thus at both ends the streams would grow.

But growth is not alone in length, but in size, or volume, as well.

The little map, Fig. 85, shows us how strangely parallel are the numerous streams which in that district flow from the Niagara escarpment to the Lake,—so evenly must the

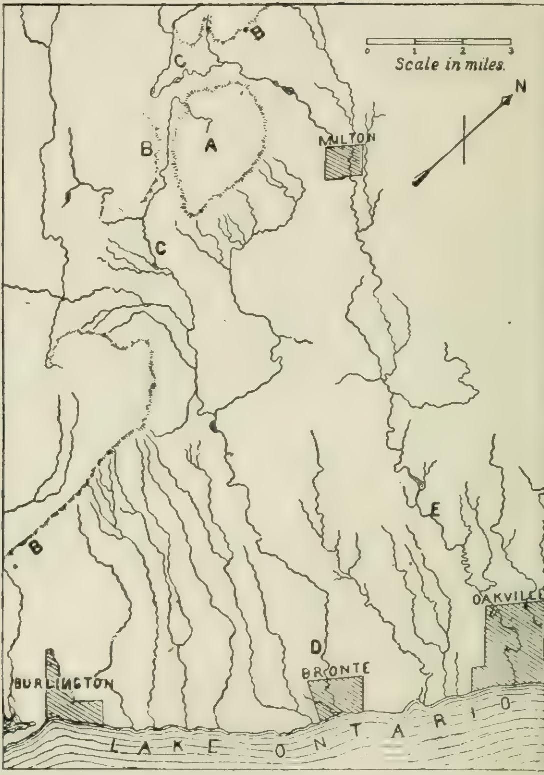

Fig. 85. Showing almost parallel course of streams from Niagara escarpment, B, to Lake Ontario; C, valleys cut in escarpment by Twelve Mile Creek, D, and Sixteen Mile Creek, E,—the Canadian Pacific Railway passing to the higher ground by the latter; A, a little plateau cut off from escarpment by streams.

Courtesy of Dr. A. W. G. Wilson, McGill University.

glacial drift be strewn there. It would almost seem as if each little stream ran directly to the Lake from its own

spring at the foot of the escarpment and in its own channel without others helping to swell its waters. But we know that no brook runs very far without some other one joining it. For with each stream-course there are three slopes, one directly down and the other two more or less diagonally towards this. These side streams help to swell the volume of water in the main one, and we always see the main stream larger below where the side stream enters it. And, of course, the more side streams there are the larger will the main one be.

But these side streams grow in length and size as well as the main stream, and moreover they come from the ground that lies between the main streams, and thus as the side streams of two neighboring main streams extend backwards, they may interfere with each other. The little map shows this danger. A side stream of D (Twelve-Mile Creek) has probably in its headward growth reached Thirteen-Mile Creek (to the east of the former) which undoubtedly ran like the others from the escarpment to the Lake, and drawn off its water into D. Thirteen-Mile Creek has been left with its lower course deprived of headwaters and greatly shortened. The same tendency to interference with others is seen in the upper streams of D to the west. Such interference of streams with one another in the process of extending and deepening their beds is very common among mountains, — and such in miniature the attentive observer will notice in freshly ploughed fields or newly cut banks during a rainstorm.

And so on the newly risen land that we have imagined, the same process of growth in volume would go on in all the streams. The increasing size of the land as new areas were ever rising from the sea and the older ones becoming ever more elevated, gave room for the streams to grow on all sides in length and volume, some at least of those that started in the deepest depressions at first keeping the lead as main streams, while the side ones poured into them their water gathered from the intervening areas often to the destruction of what were once main streams themselves.

We cannot say positively whether rivers existed in the primeval land,—the crust that first hardened over the

molten mass as the earth was cooling down to take its present appearance, for probably none of that old land now remains on the surface of the earth; if they did exist,—and we must suppose that a cooling earth had a cooling atmosphere, which means rain of some kind,—they bore little resemblance to the cool clear liquid we now associate with the word river; they must have consisted very largely of acids washed hot from a foul atmosphere which could nourish no life till after long ages had cleansed it. But the Archæan land had its rivers, how many we cannot tell, for the immense length of time to which that land has been exposed to all the operations of wind and weather, to say nothing of the destructive force of the glacier, must have destroyed most of them. But we can say almost with certainty that the Hamilton Inlet in Labrador and the Saguenay are two old Archæan rivers; both lie deep down between high cliffs, capes Trinity and Eternity at the mouth of the Saguenay rising a thousand feet in air while at their base the salt water lies a thousand feet deep.

RIVER BASINS.—VALLEYS.

One other feature with regard to the streams whose growth we have been following:—As they became longer and broader and deeper they wore away, or eroded, both their beds and their banks, so that where ground had once been there would be only hollows that extended themselves as the streams extended themselves, and broadened out and became deeper as the land rose higher; till at last there would result a few central hollows in each of which ended other though smaller hollows from each side, these in their turn having others ending in them; and so on down to the tiniest rill, the whole forming an apparently, but not really, perplexing net-work of hollows,—the "basin" of the main hollow or stream,—while each separate hollow, large or small, would be the "valley" of the stream that had furrowed it. Thus while each stream or rill would have its own valley, each would have also its own particular basin,—the area of land, from a few square feet to hundreds of thousands or even millions of square miles in size, whose surplus water drained off into it.

And as we follow in imagination the ceaseless working of these "many waters" we see how the whole of this basin (an ideal one here), must to its outmost rim—the "watershed" or "divide" from other basins—get lower and lower after the upward motion has ceased; the region about the lower river-courses where the water, gathered from a vast area inland, comes together into one strong full stream, being lowest of all; while the valleys there are wider and with more gently sloping sides, and the country is more even, the ruggedness having been smoothed away. Let us look at two great old rivers and their basins—the St. Lawrence and the Mississippi.

The streams that now flow from the old Archæan continent (Fig. 14) empty their waters for the most part either into Hudson Bay, as they did from the very first, or into the St. Lawrence directly or indirectly. But unlike Hudson Bay, the St. Lawrence did not exist in those early days, and the streams that flowed outward ran at once to the sea, not gathering into a great trunk stream as now. There were just two basins then, the Hudson Bay basin and the ocean basin; but beneath the waters of bay and ocean was quietly falling the sediment, brought into them by the streams, that in later days was to be raised into land again (Plate I. and pages 23, 24), and over this land, of Cambrian and Silurian strata, when its southern rim grew high enough to form a hollow between it and its northern rim, the St. Lawrence began to flow. For the streams could now no longer reach, each one, the sea directly, but uniting their waters, from the south as well as the north, they flowed as one trunk stream down the general slope to the ocean. Thus with the St. Lawrence the side streams existed before the main stream; and though the river has had a very varied history, yet there is reason to believe that the St. Lawrence of to-day is, in its chief features, the St. Lawrence of Palæozoïc days.

Very different is the story of the Mississippi, that greatest river and river basin of the world. We say it rises in a little lake in Minnesota and flows south to the Gulf of Mexico. But a glance at Plate I, the geological map, will show how long it has been in growing to its present size and reaching its present destination. Unlike

the St. Lawrence it was an Archæan river, though where it started it is impossible to say, for, except in one or two places, the glacial drift has blotted out all its old valley, and the little lake that now feeds it owes its own existence to the drift as well; it is a glacial lake. If it is true that the Red River's natural course was southward (page 42), in all probability the Mississippi started at the topmost rim of the old Archæan land. At any rate, its growth in length, as we see by the geological map, has been by pushing its channel across the new lands as they gradually rose in period after period and age after age in front of it, and it is still doing the same to-day. For all, or very nearly all, the geologic periods and ages have raised their strata to the surface in this great valley, and the vast amount of sediment that the river drops into the Gulf is ever rising into new land.

But not till late geologic times did it get any side streams from the west; that region was still a sea or almost covered with vast fresh-water lakes. At length the great upheaval that raised the Cretaceous and the Tertiary rocks into mountain and plateau to the west, drained the lakes and sent the streams—the Missouri, Arkansas, Red and others—into the trunk stream that was waiting for them. Pages 32, 34.

Thus while upheaval in the one case gave to the many single streams a trunk stream that did not exist before, upheaval in the other case also gave to an existing trunk stream side streams that it did not have before.

Like the St. Lawrence, the Mississippi has had some varied experiences, but that it is an exceedingly old river is beyond all doubt, for it winds back and forth in a flat-bottomed valley whose steep sides or "bluffs" are in places seventy miles apart. (See "Meanderings of Rivers.")

CHANGES IN RIVERS. As has just been said, uniformity of material in the ground over which rivers run, and uniformity of slope or elevation cannot be looked for; variations are innumerable. And though, also, the great trunk-rivers may have entrenched themselves so deeply and firmly in their courses that even great calamities, —great depression or great elevation, or even burial beneath an ice-cap,—may not be able to dislodge them, yet in their

upper courses among the mountains, where the volume of water is small and where elevation with crumpling and folding may be actively going on, changes continually occur. In many places in the third level, or steppe, of the Canadian North-West are found the valleys of old rivers, commonly called ~~"coulées,~~" some of them fully two hundred feet deep, and a mile or more broad, but without water excepting at times a narrow stream that never leaves its own little channel, or a succession of long narrow lakes, which are often alkaline.

Where Vermilion River joins the North Saskatchewan a

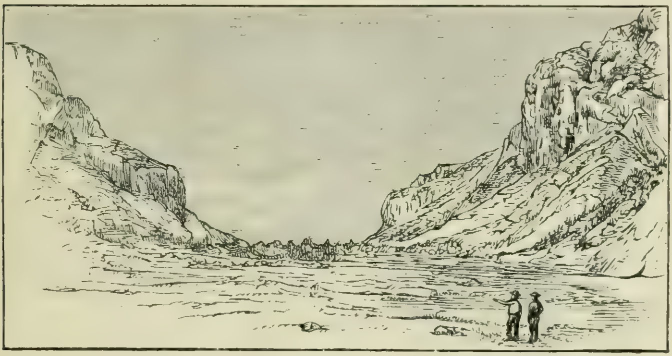

Fig. 86. Devil's Gap, eastern Rocky Mountains. Geol. Survey of Canada.

deep wide-bottomed coulée runs eastward for over fifty miles. At the place mentioned the Saskatchewan bends sharply to the north and runs in that direction many miles before turning eastwardly again, and everything indicates that this coulée is the abandoned channel of the river. The Ghost River runs out of the Rocky Mountains and after a south-easterly course joins the Bow River some distance to the east of the foot-hills; on its way it passes by the "Devil's Gap," the eastward opening of a deep, flat-bottomed but narrow valley that extends across the southern foot of the Fairholm Range into the mountains toward Banff; toward the east it is occupied by long narrow lakes, but toward the west by a small stream that joins the Bow near Banff. This cut is the old valley of a river;

either, as some think, the Bow River once ran through this to join the Saskatchewan, or as others suppose, the Ghost River, after leaving the mountains further north, turned and ran back into them through this channel to join the Bow. But the whole south-western region in this part of Canada has undergone, perhaps is undergoing still, an uplift, which has materially changed its slope and thereby altered its old water-courses, even though many of these had entrenched themselves from a hundred to three hundred or more feet deep and had formed broad valleys. These valleys, where there are no lakes or marshes,—for such would naturally occur in them,—are covered with grass or at times with forest growth, but when the soil is removed the old river sand and gravel are seen underlying it;—the winds blowing the fine material of the plains into them, the slow but certain surface wash, the natural destruction of the coarse material through the chemical action of the acids in the air, together with the decay of vegetation, have all helped to form the deep rich soil of these old river beds.

The thoughtful passenger on a St. Lawrence steamer will note with surprise that from the upper deck he can often see far over the country on both banks,—an impossibility on most large rivers, and many small ones too. The Mississippi lies in places over four hundred feet below the level of its enclosing banks, and as we have seen on a preceding page, the Mississippi in the greater part of its course is a far younger river than the St. Lawrence, so that if only age is to be considered the channel of the St. Lawrence should be far deeper than that of the Mississippi, seeing that the St. Lawrence is not down to base-level. Gorges usually occur where there are rapids along a stream, an indication that the stream has cut its way down from higher ground, but has not yet got to the bottom. There are no gorges on the St. Lawrence between Kingston and Montreal, where the rapids occur. Either, then, the denudation of the St. Lawrence valley has kept pace with the erosion of the river channel, which is hardly possible in any case, or else some other cause has been at work.

It is thought by many that the old St. Lawrence, long before glacial days, had dug out a deep valley, even down

to base level, and that afterwards the ground rose in terrace form across the path of the river between Kingston and Montreal, creating rapids on the edge of the terraces and forming beyond the western boundary of the last elevation what is now Lake Ontario; so that this lake at least was formerly part of the bed of the St. Lawrence. Had the river been able to cut down the rocks as fast as they rose across its path, there would have been no lake or rapids, but there would have been cliffs one hundred or two hundred feet high bordering the quietly flowing stream.

As the old river-bed expanded more and more into a lake, and the depth increased with the continual rise of the rocky dam to the east, the water came at last to enter the lower courses of whatever streams had flowed into the old river in that region, and finally "drowned" them,—buried their valleys more or less deeply below the surface. In this way, if the theory is true, was formed the Bay of Quinté, which is the "drowned valley" of the lower Trent; and thus it came about, too, that the old courses of many streams that flow into the eastern end of the lake from the old Archæan region of New York State, the Adirondacks, can be traced beneath the waters of the lake for many miles towards the west.

But this is not all. The bottom of Lake Ontario is nearly five hundred feet below the level of the ocean. Now, the old St. Lawrence emptied into the ocean, and a river cannot dig its bed below the level of the ocean into which it enters. So if the lake is really the old bed of the river, then there must have been a great subsidence of the land, in which the bed of the river must have sunk five hundred feet below its old level. And this idea quite agrees with what we know of the old bed of the lower St. Lawrence:—that it can be traced through the Gulf out past the southern part of Newfoundland into the Atlantic.

Beside all this we know that there are old sea-beaches, containing modern sea shells, along the lower St. Lawrence and elsewhere, high above the present river, some of them along the North Shore being nearly a thousand feet above the water. This region must, therefore, have been much lower than it is now. So, too, must have been the valley of

the St. Lawrence farther up and along the lower courses of the side streams, where now the land lies as flat as a floor and consists very largely of clay,—a state of things which can be the result only of long submergence beneath water, just as has been shown is the case with the valley of the Red River in Manitoba.

From these facts, together with others, as the finding of the bones of a whale near Lake Champlain, it seems certain that the region through which the St. Lawrence had dug its channel, sank, and that afterwards a new rise set in which

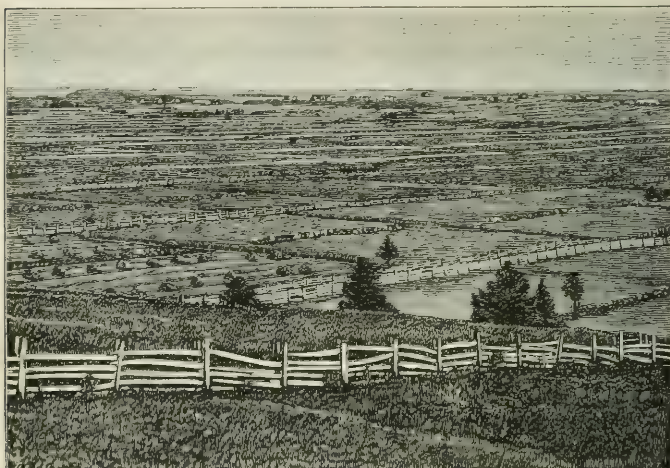

Fig. 87. Lower course of the Cacouna River, showing flat elevated valley and incidentally the long narrow farms.

Notman, phot., Montreal.

has re-elevated the region to some extent but not uniformly, one of the results of the want of uniformity being Lake Ontario. It is also quite certain that this elevation is still going on, for the old glacial terraces (Fig. 109) and beaches that were formed around the old Lake Iroquois (see page 42) are no longer on the same level, but show much difference in height above the present lake, those to the north-east being generally higher than those elsewhere. This, with the fact that there are shores on the north-east

of the lake which have apparently been abandoned very lately, and that the water seems to be encroaching on the land along the south-west shore, is taken to prove that the whole Archæan region is tipping towards the south-west.

One of the very evident "sunken rivers" is the Rhine. Its course was along what is now the bed of the North Sea, and the Thames and other rivers from England and Scotland flowed into it; while another stream flowing along the the bed of the Baltic with branches from the Gulf of Finland and the Gulf of Bothnia, entered it around the north of Denmark or flowed into the same sea not far away. The English Channel did not then exist, but England and France were united, for chalk cliffs in both countries face the Channel and thus show that they are parts of the same plateau, though now so widely separated. Holland and Belgium were much higher ground. The need of dykes along the lower Rhine and part of the coast of Holland, and the forming of the Zuyder Zee in historic times, show plainly that this region is sinking still. On the other hand the most remarkable instance of the bodily raising up of rivers,—valley, and bed, and water, and all,—occurs in the Himalaya Mountains. The face of this gigantic elevation is scored with steep-bottomed, steep-flaring valleys of immense depth. The intervening elevations, sharp-peaked or sharp-ridged, are lofty mountains many thousand feet high, composed wholly of river sediment and containing an abundance of river shells and land shells.

Thus the rivers of these regions in remote ages had cut their valleys deep down into the plateau and carried their enormous load of waste out to the sea that washed the base of the plateau, and there deposited it upon a steeply sloping bottom on which we must think was deep water; and when in later times the great upheaval began that has made this plateau the highest by far in the world, it lifted at once river-valleys and river-channels and the great mass of river deposit beneath the shore waters; then the rivers, becoming "young" again by this new elevation, not only began to cut deeper down into their old rocky beds but ploughed their way outward and downward through the

softer mass outside till they carved it into the lofty flanking mountains of the great Himalayas.

GAPS. In the Rocky Mountains rivers are often seen to pass right across a range of mountains, a thing that might be deemed impossible; these commonly have a valley with a roughly level though narrow bottom and with sides somewhat steeply retreating that often rise into mountain peaks. The rocks of the opposing cliffs are of the same character, and their varying beds are upon the same level, so that it is quite plain that no deep fault has occurred

Fig. 88. Gap of the Bow River near Banff, looking east. Cf. Fig. 86.
Thompson, phot., New Westminster.

that formed the channels along which the streams might run. It can only be that these streams existed here before the ranges began to rise across their path, and that as fast as the mountains rose the streams, through their strong current and abundance of sediment, were able to keep their path clear. Such a stream is the Bow. It crosses the Sawback and the Castle Mountain Ranges near Banff, and then passing down a valley (the "Cascade Trough") for some twenty miles, turns sharply and cuts across the Grotto and Pigeon Mountains at "The Gap" before entering the plain to the east.

In all mountain regions the same phenomenon is met with; in the Appalachians, the gap on the Delaware and on the Potomac are among the most remarkable.

ANTICLINE VALLEYS. Sometimes, too, we find rivers in other places than across ranges, where we might deem their presence impossible. Naturally in a region of folded strata we expect to find the rivers flowing along the valleys formed by the downward curve of the folds, with their side streams coming down into them from the domes on either hand. And such long valleys with their streams are common in our western mountains, though, strange to say, the same valley may have different streams occupying it at the same time in different parts of its course. The Bow is in one part of the "Cascade Trough" for twenty miles only, while other streams occupy it elsewhere. The valley, over 800 miles long, that lies between the Rocky Mountains and the ranges to the west, was not eroded by the Columbia and the Fraser that occupy its southern and middle portions respectively, nor by the Peace, whose head-waters are in the northern portion. It is a valley due to elevation, and its streams found it a valley ready made for them.

But sometimes the two banks of rivers show by the rough projecting ends of their rocks, or by the clefts that side streams have cut in them, that the dip of the beds is away from and not toward the stream; so we must infer that the river valley now occupies the place where the dome of a fold once stood. (Fig. 59 and page 82.) We saw (Figs. 60, 61) how the upturning of the broken ends of strata has led to the forming of deep valleys in the softer beds, while the harder stand out as lofty, sharp mountain ridges; but in the ones we are considering there was only folding not breaking. So we are to suppose that the tops of the ancient folds got shattered in some way by being more exposed to frost than the sides were, or by the greater strain at the top as the folds bent over to take the downward dip, and so were more subject to weathering influences. Whatever may have been the cause, hollows were eroded along the folds, and streams occupied them till at last a river-valley in the top of a fold resulted.

Such river-valleys as these, where not too old—for old age levels all distinctions,—have steep rugged sides, the result of weathering as well as water erosion, which are quite in contrast with the more regular and sloping sides of the valleys due to elevation.

RIVERS AND THE GLACIER. Frequent reference has been made in preceding pages to the effect of the great glacier upon the land surface of the country over which it passed,—interrupting by its presence the natural flow of the water in its accustomed channels, destroying these channels by wearing them altogether away, by filling

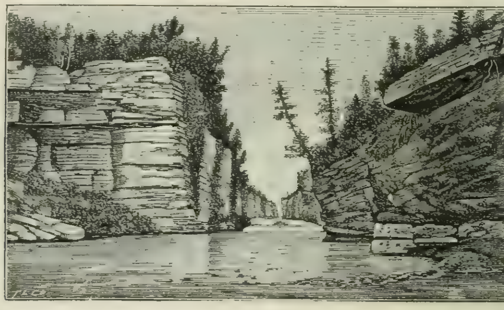

Fig. 89. Gorge (new channel) of the Grand River at Elora ; cliffs over 80 ft. high.

them with waste, or by blocking them up into lakes; the water, therefore, which, through the melting of the ice, must have been far more abundant than now, had to form new channels as the ice passed away, and sometimes, where the original slope had not been great, it took directions quite different from the flow of former days.

These new courses are always known by their "unfinished" character; they are "young rivers." The sides, where of rock, are steep, often gorge-like, as is the case with the Grand River near Elora, where the walls are fully eighty feet in perpendicular height. The wildness of the scenery along so many of the streams of the Laurentian region,—the French River, the Moon, the Muskoka, the Gatineau,—with their numerous little falls and rapids, compared with the tamer prettiness of the Gaspereau, with its flat-bottomed valley and flaring sides (Fig. 65), is due

to the activity of the rivers, for they are busy sinking their new beds down into the hard rock, which has not yet had time to moulder away beneath the influences of the weather into gently sloping sides. Their bottoms are rough and uneven, for the beds of rock that the streams must cut through, are of very varying degrees of hardness, so that they cannot all wear away at a uniform rate. Softer rocks down-stream will wear away faster than harder ones above ; these will remain sometimes as a series of ledges over which the water will pass as a rapid, and sometimes, where one mass is larger and much harder than the rest, it will remain holding out against the efforts of the water till

Fig 90. Post-glacial (new) channel of Trent below Fenelon Falls ; showing rapids. Courtesy of Prof. A. W. G. Wilson, McGill University.

all below it has been worn many feet downward and the stream pours over the obstruction as a fall.

And often above this fall there will be a long stretch of quiet water with gently sloping banks ; for here the obstructing mass below has delayed the cutting downward, for a stream above an obstruction cannot cut down lower than the obstruction; and thus the stream here is given time to take away all smaller roughnesses in its bed, and the weathering process has been able to slope off its banks.

DRIFT-FILLED RIVER BEDS.

In the Archæan region the present forms of the land surface are due in part, as we have seen, to general denudation before the glacial times; the glacier did not succeed in destroying all trace of the old work of rivers on the hard crystalline gneissic rock there; the strings of lakes so often met with are the old river-courses dammed up with the drift that the glacier left behind. But in the country outside this region, in the low-lying plain of Ontario and elsewhere, where the rock

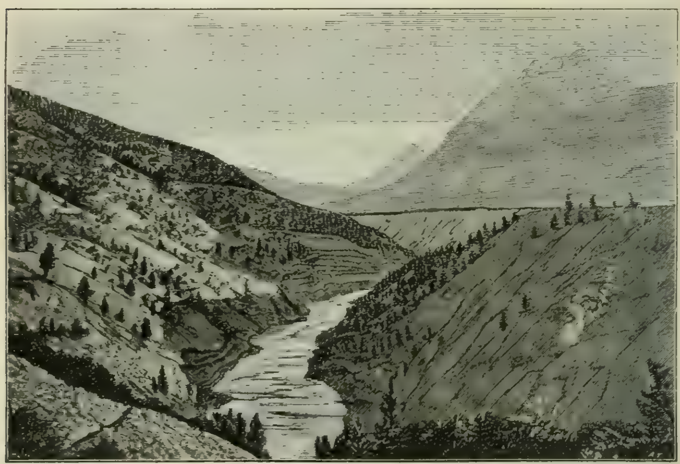

Fig. 91. Drift terrace on the Fraser River, B.C.; the river has cut down through the drift to the rock of its ancient bed.

Geological Survey of Canada.

is soft limestone, sandstone, and still softer shale, the old river courses were either rubbed out of existence or were filled up. An old river channel filled with till and other glacial matter is seen in cross section along the face of the glacial cliffs at Scarboro; while another old river bed has been traced from New York State across the Niagara River at the foot of the rapids above the falls, and then in a curved course around the town of Niagara Falls to the river again and across it between Queenston and Niagara-on-the-Lake, where the old hollow occupied by this pre-glacial

stream is recognised by the clay that now fills it, the material of the river-banks elsewhere being shale.*

In the western mountain region, which in glacial days had an ice-field of its own, the great abundance of the drift is everywhere seen. As elsewhere, it has filled up and destroyed river courses, created lakes, and where the streams have washed it out, has helped form the long, narrow, flat plains between bounding mountains so common in British Columbia. Some of the old rivers, however, the Fraser among others, have not been driven from their courses, but are now cutting down into and clearing out the immense masses of waste that once choked them. The Fraser River, it is thought, has again reached its old rocky bed, and the terraces that in places fringe the bordering mountains far above the present stream, show how deeply the valley had been filled, and what an immense mass of material the river has had to remove. (Fig. 91.)

AN OLD RIVER.† The Grand River of west central Ontario is an old river whose life goes back to long before the days of the Ice Age. Its upper course of those days is lost to us,—the drift has blotted it out; but the new stream has been vigorously at work since the ice left, forming a new course for itself through drift and rock in a very flat country (Fig. 89), till in the neighborhood of Galt it re-enters its old valley. But it does not occupy it fully, for the drift, which here is very deep and quite morainic in character, with an abundance of gneissic boulders, rises into high hills, especially on the right bank, and still fills the valley in part, though where it has been washed away the river has sunk itself several feet into the limestone rock of its bed. About four miles below the town it leaves its old valley again, (which, however, can still be seen running onward with a little stream wandering in it.) and flows to Lake Erie through a depression sometimes four or more miles wide, excepting for the last six or seven miles of its course, when it leaves the depression for another channel.

But a careful investigation has shown that this depression is deeply filled with drift, and that the top of the bed rock beneath the drift, lies at a much lower level than the surface of Lake Erie. Moreover this depression has been traced from Lake Erie, from a point a few miles west of the mouth of the Grand River, till it has been found to pass through the great gap in the Niagara escarpment, the Dundas Valley, and to enter Lake Ontario through Burlington Bay. From these facts it seems therefore certain that this old depression was the course of a great river which occupied the bed of the present Lake Erie, and

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*See paper by P. W. Currie in Transactions of the Canadian Institute, Vol. VII. Pt. I.

†See "Spencer—Preglacial outlet of Lake Erie." Canadian Naturalist and Geologist, Vol. 10.

which on becoming blocked up with drift resulted in the forming of Lake Erie. The lake rose till it reached the level where it flowed off over the escarpment at Queenston to form the "young" Niagara River and Falls.

The Grand River was a tributary of this "Erie" river, entering it a little distance below Harrisburg ; but after the ice had passed away it was turned from its former course by the drift, and followed the abandoned valley of the old "Erie" river, which, now that it was so full of drift, had a slope, though not a steep one, in the opposite direction, to the new-formed lake.

This "Erie" river, that is, the old St. Lawrence, it is thought, flowed along the deepest part of what is now Lake Ontario,—near its southern side, and gave rise, as has been said in a previous paragraph, to Lake Ontario, when the rocky barrier grew up across its course

Fig. 92. The Long Reach, Bay of Quinte: a "drowned river valley."
Courtesy of Prof. A. W. G. Wilson, McGill Univ.

below Kingston, or, as others hold, when it was blocked up here also by drift at some as yet undiscovered point. The western course extended back into what is now Lake Huron, crossing south-western Ontario from near the River au Sable to somewhere between Port Stanley and Vienna.

Another theory makes the old St. Lawrence to rise in Michigan, flow around the Bruce Peninsula into Georgian Bay, and thence across Ontario by the Trent River and Bay of Quinté into its present channel, and regards the "Erie" river as a large and important tributary of it, while all the Great Lakes, except Superior, are the result of the blocking up of this old river, or its tributaries, at different points in its course, the present points of overflow of the lakes being the lowest part of their respective rims which would lead their waters oceanward.

DEPRESSION OF RIVERS. In all parts of the world there are found long narrow inlets, "arms of the sea," penetrating deeply into the land and having rivers running into their upper ends. Such inlets cannot, as we shall see

later on, be the result of wave action, nor yet the result of upheaval, for, at its first upheaval, new land takes the form of low flat plains, and the carving of the land is done by the action of the streams. Then these inlets often extend into or across ridges of high ground, as do Baie des Chaleurs, Halifax Harbor, the fiords of Norway, the Hudson River, etc., or follow up valleys between parallel ridges, as do some of the sea-lochs of Ireland, and firths of Scotland. Soundings, too, along the course of these inlets and into the sea, often reveal a distinct channel like that of a river, as is the case with the St. Lawrence, the Restigouche, the Hudson, etc.; besides, most of these are in old regions that have been long subjected to the agents of denudation.

Hence it cannot but be inferred that these inlets are the lower courses of rivers that had reached, or nearly reached, their base level when the whole region again sank, letting in the sea to a greater or less depth. We owe to these causes the numerous "channels" and "sounds" of British Columbia and the Georgian Bay, the "Bays" and "Harbors" and "Basins" in the Maritime Provinces, and perhaps the strange Bay of Quinté, as some think.

The natural unrest of the earth's crust would make us suppose that these sunken or "drowned" river-courses may rise again, and, as has been said elsewhere, the existence along the lower St. Lawrence and the Baie des Chaleurs, of old sea-beaches high above the present water, and containing shells of shell-fish now inhabiting the waters of that region, shows that reëlevation is even now going on, but that the land has not yet reached the height that it had before the depression took place. Moreover the beaches towards the mouth of these inlets are higher than those towards their head, so that it would seem that the land is rising fastest to the east. And if so, then the water of the rivers would tend to a more sluggish flow, to broaden out, become more shallow, and be divided into two or more channels by long bars of sand and gravel dropped from the slackened current of the water. This tendency is decidedly seen in the Restigouche and is noticeable in places in the St. Lawrence. (See also pages 134-138.)

Should the elevation continue in this way the water of the river will be thrown back and flood the whole valley, which will then be a long narrow lake, and will so continue till the reëlevated river has cut down its lowest course sufficiently deep to drain it, or till a new course is found.

SEDIMENT AND ITS TRANSPORTATION.

The task that the destructive agents of nature, working in harmony, have before them, is nothing less than the undoing of what the creative or uplifting agents have done,—to carry back to the sea what originally came out

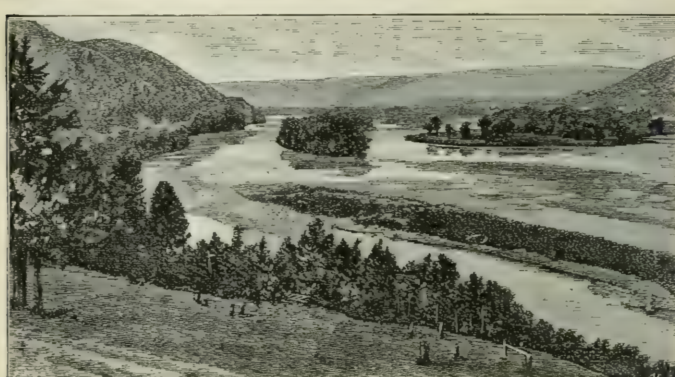

Fig. 93. The Restigouche, near Campbelltown, N.B., showing old country and broadened river with more than one channel, and sand bars.
Permission of W. Notman & Sons, Montreal.

of the sea. Rocks may be shattered by frost and heat, or worn down by ice and wind; but these agents, excepting to some extent the blind action of the wind, leave the pulverized rock almost in its place; running water alone removes the loosened material with a certain and fixed destination,—the sea.

LAND-WASTE IN MOUNTAINS. Naturally, it is among mountains that the destructive agents work most energetically, and where waste is produced in greatest abundance. Heat and cold are here most active summer and winter; the heat of the sun, even in very high elevations, is great enough at mid-day to melt the snow on the side

exposed to the rays, and the water so formed, filtering into crevices of the rock, will freeze when the sun is withdrawn, and in expanding will shatter the rock, and the fragments will roll down the sides, be carried down by snow-slides, or be washed away by the rills. The work is unceasing. The upper parts of mountains, above the line of forest growth, are found to waste away far more rapidly than the parts lower down, not so much on account of the absence of the protection afforded to the ground by the trees, as on account of the daily thawing and freezing that goes on there. It is this process that supplies the avalanches with the immense quantities of stones and waste which they bring down with them, and that furnishes the long lines of moraines for the backs of glaciers—a process that so soon grades mountains to a peak, and covers their sides with loose stones and earth.

It is not, therefore, to be wondered at that, in mountain regions, where a blind valley occurs, or where there is not enough water to form a large stream, waste should fill such valleys to a great depth. In the dry regions of the earth,—the south-western mountain region of the United States, Central Asia, Northern Africa and elsewhere, these waste-filled valleys abound,—half burying the mountains themselves from which the waste came.

TRANSPORTING POWER OF WATER. The transporting power of running water depends on different conditions. If the slope, or "gradient" as it is usually called, is steep, the transporting power is great; for if the waste is coarse it has only a very insecure resting place at best on the steep slope, and so cannot resist the force of the water as it plunges down, but goes along with it; but as the slope decreases the power of transportation will also decrease. And thus we everywhere see during a rain storm, the little hillside torrents washing down not only fine mud and sand, but large stones; these latter, however, with the other coarser material, are carried no farther than the bottom of the hill, where they are heaped up, usually as side rows, the finer material being spread out farther away, the very finest going as far as the water itself goes.

Should, however, too much waste get into the stream, no matter whether it is coarse or fine, the carrying power

is much lessened: the coarser matter will be dropped out, and the water thus relieved of a part of its burden, will carry the rest onward.

It is this sorting power of water that gives us our pebbly or stony-bedded brooks and streams. At times of heavy rains or sudden thaws the wash to the stream from the hillsides will be very great; the stream may carry much of it along for a way and then, when the storm is over, drop the coarsest in its bed, where it will remain till, worn away by the continual scouring, it will go farther. Among the Rocky Mountains the beds of the streams seldom show the rock beneath, but are usually filled deep with coarse waste; and it is a very common occurrence to meet with a stream where no water is visible, the whole course being a long string of cobble stones and pebbles, but deep down below the surface the water is found struggling onward still.

Then in a stream the velocity is not the same throughout: it is greatest near the middle, and least near the shore and bottom where the friction is greatest; consequently the quantity of waste carried along by the bottom and side currents is less than by the middle currents, but much more is deposited by the former on the bottom and sides. It follows from this that the power to transport is greater where the volume of water is greater, for much more in proportion will be free from friction than where the water is shallow.

It has been found that if the velocity of a stream be doubled, its transporting power will be increased to the extent of the sixth power of the velocity. In other words, if with a certain velocity a current can just carry along a stone weighing two ounces, with double that velocity it will carry a stone weighing sixty-four ounces, or four pounds.

HOW RIVERS ERODE.

Pure water, beyond what it can do by its onward motion, has little power of erosion; apart from the chemical action of the acids of the water, the whole work is performed by the waste that the currents carry along. The coarse material,—the gravel, pebbles, cobble-stones, etc.,—which is too heavy for the water to buoy up, is pushed along the bottom by the force of the flowing water and rubs or grinds down the rock

beneath it, while it itself is being wasted at the same time; the finer material, the fine sharp-pointed particles of sand, is buoyed up by the water and dashes against both sides and bottom, cutting off a minute portion at every touch however slight.

The more rapidly the waste is carried along, the more rapid will be the erosion; for sudden contact will produce more effect than a more deliberate one, just as a rapidly revolving grindstone will sharpen a tool,—that is, cut away the particles of the steel,—more quickly than a slowly revolving one. And so, too, the more waste the water contains the more rapid will be the erosion, provided the quantity is not great enough to check the progress of the water, or to make the water spend all its force in carrying the material onward. When water becomes so overloaded it will drop part of its burden to the bottom, where it will act as a protection and so hinder erosion.

Fig. 94. Cañon on the Fraser River, B.C., on line of Canadian Pacific Railway. Water rises here over 150 feet in perpendicular height in time of flood.
Permission of W. Notman & Son, Montreal.

It is the combination of the two conditions,—rapidity of movement and abundance of waste,—that makes streams cut down their valleys among mountains so much more rapidly than across plains where the current, and consequently the carrying power, is so much weaker. Hence in mountainous regions streams often lie in the bottom of valleys whose sides seem almost perpendicular, though there is no lack of rain or of frost to broaden them out. (Fig. 94.)

On the other hand where there is an absence of sediment

the erosion is very slow, depending wholly upon chemical action. The quantity of sediment, even of the finest, in the water of Lake Ontario as it passes out into the St. Lawrence, must be very slight; for the Great Lakes act as so many quiet settling vats where every particle of foreign matter settles to the bottom. And so the St. Lawrence has not been able to cut down its channel deeper, while other and far younger rivers, but with abundant sediment, lie down deep in their containing valleys.

EROSION BY ICE. While, however, it is the sediment in the water, driven against the banks by the currents or by the waves raised by the wind, that does the greater part of the erosion, in our northern streams the ice does its part as well. When a "break-up" occurs the full

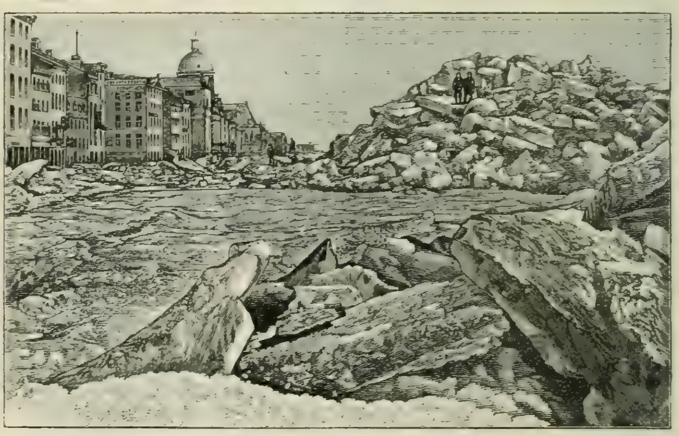

Fig. 95. An "ice-shove" at Montreal.

streams have a strong current, and the floating cakes of ice, in plunging against the banks, will break off from them fragments of rock large and small, or with their hard sharp beaks will tear them away where only drift or clay or other loose material forms them, and fields of ice moving almost irresistibly with the force of the current or "beneath the tempest's wing," as they do on all our lakes, will rend away great masses of rock, or, like gigantic steam-shovels, scoop

out the softer material, often piling boulders, and waste, and ice in an indiscriminate mass far upon the banks of an opposing shore. Any old rock-faced bank along our streams, the Ottawa or the Grand for instance, or the piers of bridges bevelled though they may be, or the timber defences of walls that rise from the stream's edge, show by their deep grooves or by their battered appearance that floating ice has dealt none too gently with them. The break-up of the ice in our rivers in the spring is a source of danger everywhere. It is this that has forced the people of Montreal to build their wharfs and river-fronts so solidly as to be the finest by far in America; and even as it is the "ice shove" is every year the cause of great expense to the city. The great mass of loose ice from Lake St. Louis is borne forward by the rapids with fearful force and overwhelms everything in its course.

Where the break-up occurs in a sluggish river, a flooded region invariably follows, as the people of the Canadian West find to their cost. It is then that the streams, which all the summer have been winding in their channels quietly backwards and forwards over the level bottom of their valleys, spread out and the whole space between valley-bank and valley-bank becomes a broad sheet of water sediment-laden. This break-up is particularly dangerous when the ice of the head waters of a stream gives way sooner than that of the lower reaches, as is usually the case in large rivers flowing north. The Red River in Manitoba, though the difference in temperature between its source and its mouth is not great, frequently does this and a flooded region is the result. Such great rivers as the Mackenzie, Yukon, and those of Russia and Siberia always flood the region about their mouths; the Yukon and the rivers of Russia and Siberia especially cover the whole region with vast beds of mud and gravel; these, on freezing, build up to an immense depth plains of river silt, gravel, boulders and ice upon which the sun's rays can produce little appreciable effect. These are the Tundras.

HOW WATER TRANSPORTS. All substances of greater weight than water bulk for bulk,—that is, of greater specific gravity,—will sink in water; even organic substances,—animal or vegetable matter,—will do so when

thoroughly saturated with water. It will make no difference whether the water is at rest or in motion;—the onward motion of the water will not interfere with the sinking of the object, any more than it will interfere with the passage of a boat from one side of a stream to the other; the boat will be carried farther down stream during the time of crossing, but it will take no more time to cross from side to side than if the water were motionless. It is just the case, in another form, of a ball struck by two forces acting at right angles to each other. How then is this stony or other sediment upborne by the water, and how can it spread through it from top to bottom?

In the first place it must be remembered that objects under water are lighter than when out of water by as much as the water they displace weighs. Then, when the slope of the bed of the stream (its "gradient") is steep, some more of the resisting power of the object, say a boulder, is taken away from it; for the down-stream side of its bed is lower than the up-stream side, and so its support against the rush of the stream is weakened. It may be, of course, that the boulder is heavy enough to resist the onward push of the rushing stream, and so it will have to lie in its bed till the slow wasting by weathering or the wearing of the sediment-filled water will make it weak enough to give way to some flood. Fig. 47 shows the bed of the stream at Grimsby just at the mouth of the gorge that the stream has cut in the Niagara escarpment. At the bottom of the cascade that exists toward the top of the gorge, heavy boulders of the fallen limestone obstruct the stream; but farther down, the bed of the stream is almost free from them, for the force of the water, which here concentrates in a narrow channel, is great enough in time of flood to carry with it the boulders that fall from the cliffs above; but when the lesser slope at the mouth of the gorge is reached, the slackened current of the stream cannot carry them farther, and they are in part piled up in the channel and in part swept to one side.

With the fine, lighter waste that is through and through the water, the case is quite different. No one can stand by the side of a flowing stream, no matter how slow the motion may be, without noticing little roughnesses like slow boiling now and then breaking the smoothness of the

water, and in these often little pieces of grass, leaves, black specks, pieces of wood, etc., will come to the surface and then sink again. In any spot at any moment these roughnesses may break out. They are just the upper ends of little currents that have been set in motion by the water at the bottom, or even in the body of the stream itself, striking against some object that has checked its regular onward flow. It may be that a stone was being pushed gently along the bottom and that it suddenly stuck fast in some little spot softer than elsewhere, and the portion of the current behind that was pushing it along, being thus suddenly checked, shot upward carrying with it besides whatever light objects it was dragging along the bottom.

Then again we must reflect that unsteadiness is created in water by the slightest inequality of any kind. The water, as has been said above, that glides over the bottom or rubs against the sides, cannot move as fast as the water elsewhere. The layer at the bottom or the side is delayed by friction against the rock or mud, while the next layer will have its quicker movement interfered with by contact with this slackened one,—and so on upward and outward, the layers at the top and middle moving fastest of all. Thus a state of continual upward movement beside the onward one exists among the particles of moving water, sufficient at all times to keep the finer particles of sediment from falling to the bottom. A rough, uneven bottom beneath a strong full current will prevent even comparatively coarse material from settling.

DISPOSAL OF SEDIMENT.

The journey of the land waste from the place where the streams first gathered it to its destination along the side of the continental slope beneath the sea, is a tedious one on account of the numerous delays to which it is subject. Were the streams all uniform in their slope, and were there no windings, or obstructions of any kind, and were the supply of water always the same, and the material of their beds and banks unchanged throughout their course; in short, were there an absolute sameness everywhere in every condition that affects the action of a river, there would be

no delays, but the sediment that is gathered either by erosion or by chemical action from mountains far distant from the sea, or from banks along the stream's course, would, when once in the stream, be continuously in motion downward till it finally reached its destination. But uniformity nowhere exists, and the final arrival of the sediment at the sea is the result of a very great complexity of action.

DELAY AMONG MOUNTAINS. We have seen that the transporting power of water depends largely upon the rapidity of its currents; and so among mountains where the slopes are steep the streams bring down great loads of waste, pushing along the bottom what they cannot buoy up; but when the current slackens on less steep ground, some of the coarser material can go no farther. Hence the beds of streams among mountains are full of gravel, pebbles, and cobble-stones to a very great depth, and often the strange sight is met with of a stream being completely swallowed up by the coarse material it has brought down from higher ground,—the bed of the stream and the water have changed places, the stones are on top, the water flows on often many feet below. Here this deposit must stay, filling up not merely the immediate bed of the small streams, but in the larger ones that do not sink out of sight, forming the level but somewhat rough bottom of a valley, a "pass" among the hills. Indeed, the masses of waste filling up these low-lying valleys that had been eroded when the streams running through them were mountain torrents, may go on accumulating, and may stay there notwithstanding weathering and wearing away by the sediment-laden water that passes over them, until the whole mountain region has been reduced to a plain. These deposits wholly stop erosion in a stream's bed. Deposits exactly similar occur where streams pass out from mountain to plain with a strong current, as is so common along the eastern face of the Rocky Mountains. Here the beds of many streams are filling up, causing the water to spread out in a wide shallow channel often broken by bars, and sometimes actually above the level of the surrounding country. The Missouri, among others, is thought to be so acting. Here, too, in the drier districts is sometimes seen

a river bursting from the ground, or a torrent of water suddenly rolling through some long, dry hollow. The season of sudden thaws and short but heavy rains, sends an unusual rush of water into the upper courses of streams whose lower courses have disappeared beneath the great accumulations of waste. This causes the outburst in the one case and the flood in the other ;—in the former the underground passages get filled up and the water has to come to the surface, and in the latter the waste in the dried-up stream cannot absorb the water fast enough.

FLATS AND BEACHES. Throughout the whole course of the river, accumulations of land waste will be found in various places, but all resulting from the same cause as fills the river beds among mountains,—the dropping of sediment in consequence of the slackening of the current, or of some other change that interferes with the progress of the water as it is hurrying along with its load, thus causing a delay.

Among such accumulations river-side flats are the most common, and are to be seen in the shelter of a projection,—some rock or other hard material breaking the evenness of the shore-line,—or where the river sweeps around the point opposite the hollow of some bend in its course. Here it is plain that the projection will make most of the water that strikes against it shoot out into the stream ; but some will "hug the shore," eddying around the point in miniature whirlpools, or with a sudden drop if the current is strong, but if only moderate, sweeping around in a slow-moving circle that brings the drift-wood back again and again to the starting point, till it chances to be seized by the onward current and carried off. Here the fish lurk.

Here in this eddy with its slackened water some of the waste carried forward by the stream will drop out, and in the course of time the nook behind the bank will be filled up to the level of the top of the water and bear a growth of bulrushes and other water-loving plants ; the bulky roots and decaying stems of these will catch and hold the sediment in the spring floods that sweep over them ; and thus will be built up an expanse of level ground that will bear grass and shrubs. Should the stream cut its channel deeper the little flat will be beyond the reach of floods, and

remain as a terrace till lapse of time washes it down into the stream again. Such little corners of land, it will be seen, even out the edges of river banks.

Should, however, the water contain so little of the finer sediment that the eddy can buoy it all up, then none will drop out, but only the coarser kinds—pebbles, etc.,—that are carried along at the bottom, will be turned aside towards the eddy, and finally, with the help of the lapping waves, will form a sloping pebbly or sandy bottom that may extend upwards into a beach.

Fig. 96. Oakville River (Sixteen-Mile Creek), flowing towards foreground: side-plain behind projection formed by eddy of stream between steep banks.

ALLUVIAL ISLANDS: SHALLOWS; BARS. A slackened current may be caused by other means than little points or bends in a river. A dam is usually built across a stream at some narrow part, if possible, just below where the banks are low and shelving, so that an obstruction a few feet high will make the water spread out widely,—far beyond the limits of the river-channel, and thus keep in check a very great quantity of water. The water that flows over the top of the dam, or wherever it is drawn off, is, of course, the same in quantity as enters the dam at the other end; but in its passage through this basin its current is

greatly checked, sediment is freely dropped, and the dam begins to fill up. Not equally, everywhere, however. The old channel of the stream is still the deepest part and has still a perceptible current, and where the sediment-laden water leaves it to spread out over the rest of the basin, the coarser and heavier sediment will at once fall, while the finer will be carried farther away and spread out more evenly. Thus islands will be gradually built up just as the river-side flats are built up; but they will lie along the channel where the coarser and more abundant material first falls. It is only a question of a short time, however, before these dams fill up completely except the channel, where the current will be in consequence much quickened in its flow. In the older ones that still exist, much of the bottom from the sides outward is bare in summer,—a bottom of rich silt that shows no signs that bed rock may be only a few feet below.

Along the courses of rivers just such islands may occur. The river, after passing over a region whose underlying rock is soft, enters upon another where the rock is hard, as the Churchill does on leaving the softer limestone and sandstone of the prairies to cross the hard Archæan gneiss on its way to Hudson Bay. The river cannot cut down the hard rock so rapidly as it can the softer, and it cannot cut its channel in the soft rock up-stream deeper than it does the channel in the hard rock down-stream. So above the area of hard rock there will come to be a long stretch of the river whose bed will be practically level, and hence the current will be slackened, the water will try to spread out more, partly from gravity,—its own weight,—as we have already seen, and partly through the sediment falling to the bottom. Erosion of the banks will in consequence be more rapid and the stream will broaden; and, as in the dam, with the broadening come a slacker current and more dropping of sediment, till as a result the river will be narrowed again by the presence of "alluvial" islands,—long, narrow and low stretches of river silt lying for the most part near the deepest channel. But in rivers such islands are liable to be removed again; for the continual filling up in one part of the river, or the work of an unusually heavy flood, may so

change the currents as to direct them and the floating ice they may in spring time contain, full upon the island whose soft material can not long resist such attacks.

On the St. John, where above its lower course the river is very broad, such islands, or "intervales," as they are commonly called, are especially numerous, and in places, particularly where the Jemseg River enters it, the steamers and other craft seem at a little distance to be sailing across meadows and through forests. The islands are largely cultivated, and, except where covered with trees, bear heavy crops of hay and grain, though few, and these the

Fig. 97. Alluvial islands on the St. John; large high island in the foreground; main channel of river; another island; inshore channel traced beyond; hills in background. Cf. Fig. 84

highest, have dwellings on them. Shoreward from the islands the river is shallow and freezes in winter, permitting the hay to be removed across the ice from the barns, and large stones to be drawn from the mainland to line the edges of the islands where they are exposed to attacks from the currents and the floating ice.

Bars in the beds of streams are long narrow accumulations of sand or pebbles, seldom if ever rising to the surface, and running sometimes lengthwise of the stream, sometimes at different angles athwart it. They are the result of the meeting of currents running in different directions, the

contact causing a short slackening, and consequently a deposition of sediment, before the united waters move on in one direction. Bars do not form in quick-flowing streams unless they are overloaded with waste; but where the course of the stream is through a plain, and the current is unsteady through the occurrence of disturbing floods, they are numerous. Naturally, we look for them where one stream flows into another; and here they are sometimes seen to extend across the receiving stream, creating a shallow from one side to the other, often with a current much stronger than that above or below. They are met with, too, where irregularities in opposite banks create currents that, crossing the stream, meet midway. Such bars as these latter are a source of great danger in river-navigation. So long as the water maintains a uniform flow, they keep their position and are well known; but when a flood comes, the plunging force of the stream and its eroding power are greatly increased, and cross currents are indefinitely multiplied; then bars will disappear in a night and form in a night, so that where a few hours before there was deep water with an open channel, there is now a shallow or a bar, upon which an unsuspecting craft may find itself suddenly aground. This is the great danger in navigating the Saskatchewan and other rivers of the Canadian West, as it is also in an eminent degree with the far greater Mississippi, along whose course continual watch is kept on the movements of these shifting deposits that thus loiter on their way to the sea.

The same in principle as the formation of alluvial islands is the formation of ridges along the edge of the river as it takes its course through a flood-plain. When the channel overflows upon the low-lying land, more sediment falls on the edge of the stream just where it begins to spread out over its banks, and so a ridge or natural embankment to the river is built up, several feet higher than the ground inside. One result of this is, that this lower ground is often wet and swampy, a feature quite common at the mouth of our little rivers near the lakes; for the water, though higher than the river, cannot drain off into it; indeed, streams often flow along inside this embankment till they get a chance to enter the river.

When a heavy flood comes this bank is often broken through and the stream pours over the low-lying region inside doing immense damage, as is often the case with the Mississippi and the Po. Fearful destruction of life and property occurred a few years ago when the Hoang-Ho in China thus burst its embankments. This danger is greatly increased where the river is down to the base-level, and the great inflow of mud-laden water from the rapid side-streams brings too much sediment for the slower main stream to carry off. Then a great deal settles to the bottom of the river and thus raises the water higher, and so makes a break more possible. In places along the Po the government has to keep continually adding to the embankments, which are thus growing higher every year, till at Ferrara the level of the river is actually higher than the roofs of the houses,—a cause of great anxiety to the inhabitants of the city. It is well known that the Mississippi has artificial embankments,—"dykes" or "levées,"—all along its lower course; otherwise the broad valley-bottom, or flood-plain, would be so exposed to inundations that it could not with safety be inhabited. Levées protect St. Louis, New Orleans, and many other cities along its banks. Man's struggle with these rivers has not been wholly successful.

FLOOD-PLAINS. River-islands are, however, only a stage in the entire filling up of the space between the river-channel, or the islands, and the shore, as we have seen above in the case of dams. The growth of the alluvial land is outward from the shore as well as shoreward from the islands; for the wash from the land uniting with the sediment in the water builds up more quickly than the sediment alone does farther out. Thus one of these island-filled rivers may have more than one navigable channel, one, however, being the main channel. The Amazon has many such secondary channels, one of which is over a thousand miles long, with openings only where the larger rivers enter the main stream. These channels, on account of their slight current, are the pathway of boats going up this river.

But the time at last comes when the whole of the space between the main channel and the shore is filled up; then

only when the river is in flood does it spread out again from bank to bank of its valley, still leaving, as it withdraws once more, a deposit of sediment to enrich and still further build up its now flat valley-bottom,—its "flood plain." The sides of the channel to which the stream is now again confined, rise just a little above its summer fullness, but they are no longer of rock; they are wholly of the soft uniform silt that the river itself has brought and laid down there, moulding them, as it were, into a shape to its liking,—curving downward steeply concave beneath the water and rapidly flattening to mid-channel where they meet in a level bed.

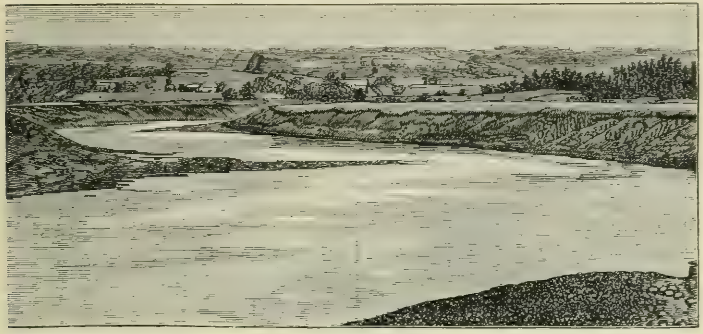

Fig. 98. Tidal river in alluvial plain; low tide; showing curves of banks beneath high-water level. Cf. Fig. 100.

A flood-plain may occur anywhere along a river's course where an obstruction causes a delay in bed-erosion up-stream long enough to allow the river to broaden its channel by eroding its banks, and to deposit the waste where, through broadening, it has become shallow. The river in thus doing goes to the banks, so to speak, digs them away, and carrying the material outward builds up with it a new groove through which it can glide without encountering the roughnesses of its old one.

The flood-plain that, beginning with the mouth of a river, extends backward up-stream, is the only one not in danger of being left as a terrace, unless, indeed, the whole basin receives a new uplift, for it is down to sea-level and can go

no farther. Here the river will direct all its efforts to widening its valley and increasing the size of its flood-plain, so that this lowest valley-floor will be the largest and most important of all, and in the course of time, through repeated floodings and the accumulation of decayed vegetable matter, with what the wind will bring, it will rise so high that only a little danger from floods will exist, and what danger there may be will be largely removed by the dykes that will be raised by man, who will come to inhabit and to till its rich soil, as is the case in very many other places than in the valley of the Po and the Mississippi. (See Fig. 101). In Egypt, however, no dykes exist, and Egypt is nothing more than the long narrow flood-plain of the Nile, a river that for the last five hundred miles of its course has been down to its base level from remotest antiquity. There is no rain in Egypt, and the flood which, coming every year, spreads out over the valley with a breadth varying from four or five miles to twenty, brings with it the water needful for vegetation and the sediment wherewith to enrich the soil. Dykes would destroy the country. The great dam at Assuan, just completed, will still further extend the flood-plain by millions of acres, man here coming in to do what nature cannot do.

Many of the little streams entering our Great Lakes have little flood-plains at their mouth. The Don at Toronto is perhaps the best example of this. For a stretch of over a mile there is a fine little flood-plain through which the stream used to wind its once serpentine course, overflowing "the flats" in times of flood and withdrawing into its muddy channel when the supply of water fell. The stream has now been straightened, a new channel, where needed, having been dug for it, and confining dykes faced with timbers raised along its sides. In others this flood-plain has either not yet been fully formed, or is being removed by "dissolution," (the quiet removal of sediment by chemical action, which is the final stage of flood-plains), a swampy condition in which mud and water are scarcely to be distinguished one from the other. The stream at Grimsby has also a flood-plain inside its bar, but in places it is like islands, covered with trees, the stream being shallow and flowing over a stony bed.

The delay in the progress of sediment sea-ward caused by one of these obstructions is not lost time in the river's work; for while the harder rock of the obstruction is being cut down, the valley, as we have seen, is being broadened above it; and this must take place ere the whole basin can be brought down to base-level. So while the Nelson is cutting its way down and back through the hard Archæan gneiss of its lower course, the Saskatchewan has been eroding a wide, deep valley and forming a flood-plain; thus much of its work is being done awaiting the time when Lake Winnipeg will be drained, and when the flood-plain, having become a long terrace, will be a series of farms and their dwellings, with no danger of flood from the stream that once more is actively engaged in deepening its channel. The city of Fredericton in New Brunswick stands on one of these old terraces, which the deepened bed of the river has left out of reach of floods. The old rocky erosion-bank of the river, with the marks of erosion still on it, lies on the side of the city farthest from the water, while beneath the city is a dark silty soil, scarcely more than a foot deep, resting upon a bed of coarse but even-grained river-sand.

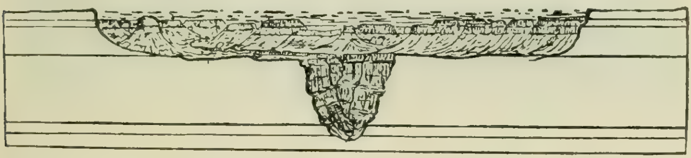

Fig. 99. Section across Colorado River; old valley bottom 2,000 feet below general level; depth of channel cut since re-elevation, 3,100 feet; width of old valley at top, over four miles.

RE-ELEVATION OF RIVERS.

But a worn-down river valley, or a river-basin, may again be raised as we have seen is the case even now with the Restigouche and other eastern Canadian rivers (page 145), and possibly with the upper St. Lawrence also. Perhaps the most remarkable example of such re-elevation is that of the Colorado in Arizona. The present river, almost one continuous rapid, lies at the bottom of a gorge in places over four thousand feet deep, with almost perpendicular sides, the gorge itself dropping from the bottom of an old

river-valley sometimes seven miles wide, between bounding terraced cliffs two thousand feet high. The valley is an old flood-plain from which all sediment has been blown away in that dry climate, and its level bottom and great width show that, before re-elevation began, the river was down to base-level. When re-elevation set in, the water, as is natural, drew together to one place and cut its way downward, the walls of the chasm weathering comparatively little. The rocks through which the river has cut, are of many kinds, but the marble ones are the most massive, and their strange carvings and often brilliant colors are very striking.

Fig. 100. Meandering brook flowing from mineral springs at Caledonia Springs, eastern Ontario. Springs about a hundred yards back of foreground; brook discharges into a larger in front of buildings in background.

MEANDERING OF RIVERS. Rivers act strangely in flowing through these wide flood-plains. If we pour some water slowly on a perfectly level surface, it will spread out on all sides; on a surface with a sharp slope it will at once run straight down; but if the slope is very slight the water, while following the general direction of the slope, will be turned aside by the slightest obstruction,—a little inequality not perceptible to the eye, a grain of sand, or even a particle of dust, so that the miniature stream will wind from one side to the other in a strangely serpentine course.

Fig. 100 illustrates the last peculiarity. The country around is perfectly level to the eye (Fig. 76), and its streams,

of which there are very many, have all the same meandering course, tending towards the Ottawa. They lie deeply entrenched in the pink clay of which the whole region consists, and have, especially near the Ottawa, narrow bottoms to their little valleys. When this region was abandoned by the post-glacial sea that covered it for a time, the spring, if in existence then, was on a level with the surrounding land, and the little brook that its overflowing waters formed, moved away in its meandering course along the surface of the ground to join with a larger brook. And since then it has kept on quietly in the same channel till it has made a little valley for itself some fifteen feet deep, with long hollow-curved tongues pointing towards hollows on the opposite side (Cf. Fig. 98).

Fig. 101. Cornwallis River, King's Co., Nova Scotia ; a tidal stream flowing into Minas Basin. Stream flows towards foreground. Dark bands skirting stream and crossing tongue lowest down are dykes, outside of which the tide covers at spring-tides. Within a direct distance of seven miles the length of the river through its meanderings is not less than twenty-five miles.

But this little stream had its level ground to start with, while rivers have to build theirs up by their own efforts as we have seen, and the original crookednesses are no help in forming these new curves. Nor need the flood-plain be fully formed before the meanderings begin ; it seems to be sufficient if the bottom of the valleys is in progress of filling up. Fig. 101 shows a river meandering through its flood-plain which is here about a mile wide. The curve on the left has reached the side of the river-valley, but those on the right have not yet done so ; but it will be seen that these curves are approaching the bank, as the dyke crossing the lowest tongue, when built, was close to the river. For some of the sediment that the river digs from the

hollow on the left, drops out in the slackened water in the eddy around the point where the stream makes a new curve, and so extends the point; and at the same time the stream is digging out this latter hollow more deeply and carrying the waste down stream to be deposited, some of it, around the next point below.

USE OF MEANDERINGS. It will be noticed that in its meanderings the river runs diagonally toward the sides of the valley, and so its power of erosion is far greater on the spot where it strikes than it could be if the water glided slowly down parallel to the sides. The water in plunging against the bank, beside being turned off to the other side of the flood-plain again, digs the curve deeper and down-stream as well, so that we must believe that in the course of time a curve,—the hollow,—will travel the whole length of the river valley. Thus, while feebly flowing water would have little eroding effect on the banks of a straight stream, in these curves the current is greatly quickened by the pressure of the water above them as it is forced to change the direction of its flow. It is by means of this travelling from side to side that rivers, where down to base-level, increase the breadth of their flood-plains, and the great age of the Mississippi may be judged from the great breadth of its valley, which is fully seventy miles in its broadest part.

Another peculiarity in these meanderings is that the stream is often, through the depth to which a curve is dug, actually turned backward on its course, and the next loop is farther up-stream than its predecessor. In this case the tongue of land between the arms of the loop is dug into from both sides near the base, with the result that it is at last cut through, and the river, using this new channel, deserts the loop. Then the ends of the deserted loop are soon blocked up by silt, and what was once a part of a river is now a crooked, or "ox-bow," lake,—which in time fills up and disappears. Such lakes are very numerous along the great flood-plain of the lower Mississippi.

DELTAS. The lower end of the up-river flood-plains is where the river has to pause to cut its way through the obstructing hard rock; but the last or lowest down flood-plain has no stopping place of this kind: it opens out to the

sea. Here, however, it usually comes in contact with the ocean currents and can extend no farther, for the sediment that the stream brings down, and that would otherwise be deposited here where it meets the salt water, is swept away to be deposited far off along the slope of the continental shelf (page 51, note), so that the growth of the flood-plain seaward is stopped. But when the stream enters the waters of a bay or an inlet of the sea where only the ebb and flow of tides produces currents, or the still more quiet waters of a lake, there the flood-plain still continues to advance. It has no side-erosion to supply some of the sediment, and no banks to check its spreading out: all the material is brought by the river itself, and the spreading out takes its own course. The sediment has reached its destination.

The sediment, as the river enters the quiet waters of the inlet or lake, drops to the bottom across the river's course and eddies off towards the sides, so that an area of new land is built up, rapidly where the sediment is abundant, slowly where the supply is more limited; and when it rises from the water,—in all respects as river-islands and flood-plains do,—it has the general shape of a fan or of a triangle with its apex at the point where the river first entered the sea, its base presenting a general curved outline towards the open; hence it is called a "delta," the name of the fourth letter of the Greek alphabet, which is triangular in shape.

Across this delta,—this new flood-plain in the sea,—the river holds on its way, but not as a single stream. It builds up, as we have seen (page 159), its immediate banks more rapidly than it does the space beyond, so that while the latter is a mere marsh at the level of the sea, the banks may be even several feet out of water and covered with shrubs or trees. Such embankments can offer only a slight resistance to the river in flood; they are over-topped, burst through or washed away in places, so that new streams* are being continually formed, draining off to the sea diagonally to the right and left in smaller channels from the

*It is proposed to call these streams "distributaries" as opposed to "tributaries,"—streams which add their water to the main stream, not take water from it as these do; they might very properly be called "branches," were not this term already applied, though quite improperly, to tributaries.

main one, and dividing and subdividing, and interconnecting in a maze of canals whose waters creep sluggishly in every direction, overflowing to build up their surroundings when the main stream overflows, and as often changing their position. But as the delta grows older and higher these streams, except the largest, which usually leave the main stream where the latter first reached the sea, are filled up and disappear, just as do the channels between the river islands and the shore, and the "ox-bow" lakes left by a cut-off in a river's meanderings. This feature is noticeable in the cut (Fig. 102) of the united deltas of the Ganges and Brahmaputra; the northern or older part, which is thickly inhabited, has few streams in comparison with the southern or lower part, which is a flat steaming swamp, covered with a dense growth of shrubs and trees, the great jungle of the "Sunderbunds."

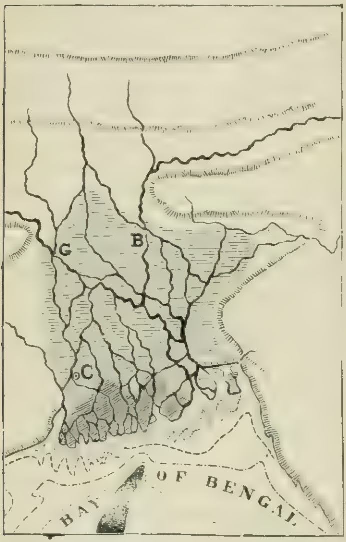

Fig. 102 United delta of the Ganges (G) and the Brahmaputra (B). Part dark-shaded, the Sunderbunds; lightest shaded, naked mud just at level of water. (C), Calcutta.

It would be naturally expected that where a river thus discharges into a body of deep water, the alluvial beds forming below its surface would slope away gradually and uniformly; but such is not the case. The immediate front of the rising delta beneath the water is quite steep and advances in this shape over the layers of the finer sediment that was carried out farther into the deep water. The cause of this steep front is mainly that a very large proportion of the waste brought down by the river is here, as it is all through the lowest flood-plain, in the form of liquid mud which is pushed along the bottom of the river rather than upborne by the current; and so it drops down to the

bottom just as soon as it reaches deep water. The river is, as it were, an endless succession of carts loaded with earth, which, when the carts are dumped, slides down into the hollow that the workmen are engaged in filling up, making its own slope as it does so.

The base of the delta can be regarded only in a very general way as rounded, for the sediment could not be distributed equally everywhere ; if it could, the form would necessarily be rounded ; and the various currents of the receiving body of water interfere, too, with regularity in deposition. Again, though the "distributaries" take so much water from the main stream, yet the latter remains the largest by far, and so tends to advance its part of the delta more rapidly than elsewhere.

Some of the deltas thus formed on the sea-coast are very large. That of the Ganges has an area of between 50,000 and 60,000 square miles, and has been bored into to a depth of 481 feet without finding anything but river deposits ; at the mouth of the Danube is another great delta, which in places is advancing seaward between 300 and 400 feet a year ; the delta of the Nile is 180 miles wide along its face, and extends inland over 90 miles ; the delta of the Po is rapidly filling up the head of the Adriatic ; towns now 20 miles inland were seaports two thousand years ago. The delta of the Mississippi has an area of 12,300 square miles, adds about 262 feet yearly to its front, which is 220 miles from its upper point. A peculiarity in this delta is that the main stream and the chief "distributaries" first build up long arms extending into the Gulf of Mexico, and then dividing again, each stream forms other long narrow pieces of land like outspread fingers. The front is, therefore, very irregular. Some of the irregularity is probably due to the fact that there is a current flowing past the front of this delta, but the amount of sediment in the river is so great, and the quantity of water so large, that the force of the current cannot stop the progress of the delta.

The delta district at the mouth of the Fraser River is not one of the typical deltas referred to in the preceding paragraph; it is more like that of the St. Clair, a number of low alluvial flood-plains and islands, so low and flat that in the case of some, such as Lulu Island, dykes are built around the shores to protect the island from inundation. This alluvial district extends far up the river ; in the Agassiz district, sixty miles from its mouth, the river has a wide flood-plain on its north bank.

Naturally deltas are readily built up in the quiet waters of lakes, and here their results are best seen; for the

sediment is not carried away by currents, but falls where the streams enter the lakes. And so it is only a matter of time, and in many cases not a long time, ere such lakes with their limited areas become filled up. The Rhone enters Lake Geneva a muddy glacier stream, and flows out at the other end clear and blue; but it has built up a large delta at its upper end which contains a busy population. Lake St. Clair must in the not distant future be filled up, for though the quantity of sediment brought by the St. Clair River into it is not great, being derived only from the shores of lower Lake Huron, yet the delta of that river, though in the form of islands, is surely, if slowly, advancing southwards. The islands and the marshes at the mouth

Fig. 103. The delta district at mouth of the Fraser; ground "as level as a floor."
Edwards Bros., phot., Vancouver, B.C.

of so many of the small streams emptying into our Great Lakes,—the Grand, the Don, the Humber, the Trent,—are all of the nature of deltas, needing only to be more fully connected one with another to make them really such, for they are all alluvial. But our great river, the St. Lawrence, has no delta though its mouth is far removed from oceanic currents. As has been already explained, the Great Lakes take all the sediment out of the water that is to form the St. Lawrence. What little the river may gather in its passage seaward,—and it can gather little, for as it takes money to make money so it takes sediment to make sediment,—is again taken from it by the many lake-like expansions on its course, — Lake St. Francis, Lake St.

Louis, Lake St. Peter, and others, so that when the water finally reaches the Gulf there is practically no visible sediment in it to deposit; though if the waters of the Gulf could be drained off, there would be found over its bottom a deep layer, not indeed of river waste, but of chemical deposits of various kinds, compounds of lime chiefly.

Wherever one stream enters another there is apt to be a delta-like deposit built up, sometimes as alluvial islands, sometimes as shoals of coarse material such as pebbles and gravel, that force the receiving stream against the farther bank, making its bed crooked, or again as wide bars that by extending across the stream, will pond it back, delaying erosion above the dam and creating a shallow rapid.

In dry mountain regions where the streams are only torrents lasting for the most part only during the period of rains, we see on a large scale what we see at the foot of a hill after a rainstorm,—a delta-like accumulation with a steep rounded face at the mouth of a gorge, sometimes only retaining little ridges to mark where the water spread out in shallow channels, or flowed almost evenly over the whole surface, and sometimes carved into chasms where the stream has cut down deeply into its own previous deposits, carrying its new load farther out into the plain below.

RAPIDS.

Rapids are merely a feature in a stream's younger life; like lakes and falls they belong to streams whose work is not yet done. Erosion is very energetic where they exist, and they disappear as the bed of the stream sinks nearer and nearer to the base-level. A stream in eroding its channel downwards may create its own rapids; for in passing from a region of hard strata to one of softer strata, the rocks of the latter will wear away faster than the harder rocks above, and a rapid will result, which may indeed turn at last into a waterfall if the difference in hardness of the rocks is marked, and the hard ones are tilted. Such rapids as these, interspersed with low waterfalls, are met with all along the inner and outer rim of the Archæan area where the streams pass from the gneiss to the bordering and softer limestone. And within

the gneissic region itself the different varieties of gneiss vary much in hardness, and, as a consequence, rapids are met with on many a stream rushing tumultuously over the rough bottom of rugged-walled gorges sometimes a mile or more in length. But as these streams are all new ones, having, as it were, sprung into existence on the passing away of the ice-cap, their rapids are in a great measure due to the unevennesses in the ground which had been plowed over by the glacier, and had been eroded by other streams and weathered into manifold forms during countless centuries before the glacier appeared.

In mountain regions, especially where upheaval is still going on, the streams are naturally little more than a series of torrents, cascades, and waterfalls; only where a larger

Fig. 104. The Lachine Rapids,—the St. Lawrence leaving Lake St. Louis. A skiff shooting the rapids.

Notman, phot., Montreal.

stream flows along a valley that it itself has dug out, or that, like the valley of the Columbia and Fraser, lies at the bottom curve of a fold of strata, are true rapids seen. For on such streams long stretches of quietly, though strongly, flowing water alternate with more or less steep descents in the stream's channel, where are the real rapids.

But old worn-down river beds may be upraised again, and then the old work will be renewed; new rapids will be formed by the upheaval, as among mountains, or by the river's own work. Such has been the experience of the St. Lawrence if the theory regarding its re-elevation is true (pages 134, 135); the unequal character of the elevation, taking a terraced or staged form, has caused rapids

wherever the rise is abrupt. The famous cataracts of the Nile, six in number, are only rapids rushing down the steep drop from one terrace to another in the river's course to the sea. It was in overcoming these that Lord Wolseley found Canadian "voyageurs" so useful to him.

Then again, rapids may result from other causes. The presence of drift in the streams causes many a little rapid in the drift-covered area,—a rapid whose bed is not rock, but pebbles and cobble-stones. The coarse waste discharged by one stream into another has often been seen to fill up the channels of the latter to such an extent that a rapid is formed by the water from above in passing over it.

WATERFALLS.

Along the course of any little brook we often see the water making a miniature leap down some sudden descent in its channel,—a trunk of a tree embedded across it, a boulder, a little rocky shelf, a bed of hard clay, or anything that will not wash away as fast as the other material along the brook's course will do. It is the same with great rivers: a sudden descent, however formed, occurs along its course, and the water leaps down it to the level below.

Such sudden drops in a river's bed may occur anywhere along a stream except where base level has been reached, for waterfalls on a stream's course show that the stream has not yet finished its work. But naturally we look for them chiefly in the rugged ground where the rivers originate. Here upheaval has gone on so very much faster than the streams could cut down their beds, that the streams and their channels have both been carried upward as well as the surrounding rocks, and thus steep descents have been formed down which the water pours, or makes a wild leap over perpendicular cliffs sometimes a thousand feet in height, as does the famous Takakkaw Falls in the Canadian Rocky Mountains.

But such upheaval alone, unless where a fault takes place, could hardly produce the perpendicular, or almost perpendicular, cliffs needful to cause a waterfall. We have seen in a former chapter that among the Rocky Mountains the different strata are of very varying degrees of hardness; that they are folded and broken, often tilted on edge, and

that deep valleys are dug in the softer ones. Across these varied strata streams make their way; they cannot erode the harder strata as fast as they can the softer. So when a stream, after crossing hard strata, comes upon soft strata it will erode the latter so much more quickly that the hard strata will be left standing out as a cliff over which the stream will form a waterfall. This is the way most waterfalls have been formed.

The falls in our Archæan region have all been thus formed, the Bala Falls for instance; for although the

Fig. 105 "Natural Steps;" first stage of Falls of Montmorenci, a short distance above the precipice. Walls of young gorge almost perpendicular; upper beds of horizontal strata weathered into "steps."

streams flow over hard gneissic rock, yet the gneiss is of different kinds and varies very much in hardness or in the readiness with which it yields to the action of water.

Should the strata lie flat and be of a kind that readily splits into blocks, a fall in the form of a succession of stages,—a "cascade,"—will be the result; and along its sides step-like shelves will often be seen, as shown in the engraving (Fig. 105). The Montmorenci, at a little

distance above the point where it leaps from the edge of the precipice to the St. Lawrence below, has cut its way down into the limestone in successive stages leaving, at one side at least, the thin layers of rock rising above one another in "natural steps." But it will be noticed that the sides are on the whole nearly perpendicular notwithstanding the roughnesses caused by the projecting shelves,—a peculiarity everywhere seen along a gorge cut in horizontal strata. The water penetrates the joints of cleavage and, helped by the frost, loosens the blocks one from another (see Fig. 41) and they fall, leaving a perpendicular wall.

In our Archæan region, whether it be at rest or in the course of re-elevation, the streams are all "new" ones, and the falls are of the streams' own making. They are not high, for it is an upland region only, though an old worn-down one, with none of the giddy heights so common in the West,—except where in Labrador the Hamilton River pours over the great cliff into that old pre-glacial river-valley, the Hamilton Inlet. When the ice cap passed away from this Archæan region the streams had to seek out new courses, and in entrenching themselves in the gneissic rock encountered beds of very various degrees of hardness, and, as in the newer mountains of the West, falls resulted from the unequal erosion thus caused. Doubtless the new streams found many an old hill that had been carved into shape in preceding ages, and ran down them as rapids. Possibly, too, the little falls that lie on the streams which connect the strings of lakes in this region,—on the Indian River at Port Carling, for instance, between Lakes Rosseau and Muskoka,—are the original irregularities in the beds of the pre-glacial streams that occupied these depressions.

Naturally we meet with falls, though not large ones, where the streams from the gneissic rocks pass over to the softer limestone ones lying around both their inner and their outer border. Falls and cascades characterize the streams that run from the old Laurentian region as they enter the newer Red River valley, just as they do the streams flowing inward to Hudson Bay, or outward toward the low lying land of the St. Lawrence basin. A like series of falls, cascades, or rapids is found along the whole length of the Atlantic border of the United States, where the streams

pass from the old worn-down region of the Appalachians to the lately elevated coastal plain: — scarcely a stream is without its falls.

The streams, however, that seek Lake Ontario over the Niagara or the eastern escarpment have not had to form their own cataract-cliffs; the escarpment was already there however formed, whether by uplift or by wave-erosion; and when the ice passed off the newly formed streams had a sheer cliff to leap from waiting across their path. The falls on some of these, as seen in Fig. 106, have not yet

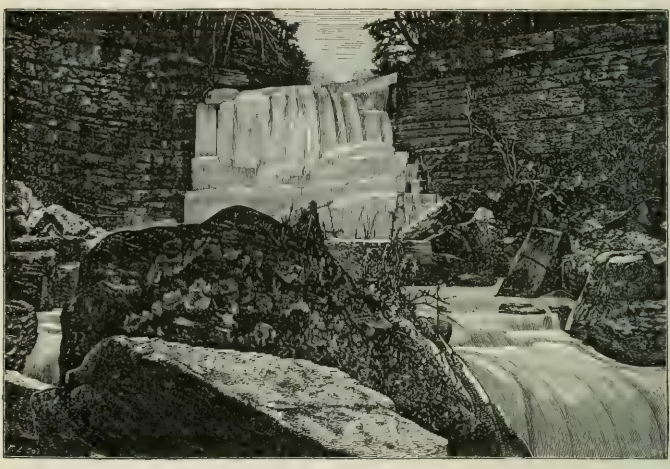

Fig 106. Lower De Cew Falls, Twelve Mile Creek, near St. Catharines, flowing over the Niagara escarpment. Retreat of the fall has left a shelf strewn with boulders fallen from escarpment.

cut very deeply into the rocks of the escarpment; others, as on the stream at Grimsby (Fig. 47) and at Dundas, have cut back to greater or less distances, but are very much lower than when they fell at first over the lofty edge of the precipice. The gorges they have cut in their retreat have a steep gradient and the water that courses along them forms rapids or even little cascades; and without exception the bordering walls, unless where the talus covers their base, are perpendicular.

The great Niagara Falls form but one of this escarpment series. We have seen (pages 144, 145) that no river

flowed here in pre-glacial times; on the contrary there is evidence that rivers crossed the course of the present stream, and that when the drift had choked up these and closed the Dundas valley course of the "Erian River," the resulting lake, Erie, found the lowest depression in its rim at this point; the stream that carried off the overflow, after a journey of about fourteen miles, fell from the edge of the precipice into the great Lake Iroquois, now shrunken to the much smaller Lake Ontario.

Since the day of its first leap the fall has gone backward some seven miles, leaving behind a wide deep gorge with bordering walls and their talus like those of the other gorges along the escarpment. But though the cataract has retreated so far, and the river in the gorge is a rapid, yet the height of the fall is still over 160 feet,—the Canadian Fall 158 feet, the American 167. This state of things is due in part to the great volume of water in the river, and in part to the nature of the strata beneath the stream. The enormous mass of water falling from such a height produces by its very weight an exceedingly great destructive effect on rocks with such a ready cleavage as the limestone of this escarpment. Far greater, however, is the effect produced on the bed of the stream by the masses of rock that have fallen from the cliff, and that, however great, are rolled hither and thither and dashed against each other by the fearful strength of the tumultous currents in the cauldron beneath the fall. The furious water, it has been fully proved, after dashing the boulders about in the gulf beneath the fall, carries them down stream, till where the current is no longer able to move them, they lie spread out and with sand and gravel and pebbles form the floor of the stream,*

But this is not all; this would not keep the cataract-cliff perpendicular, or make it overhang as it does here. Limestone forms only the upper and harder beds of the strata, beneath which, to the base of the falls, is a thick mass mainly of shale,—the mud-formed rock, that on being exposed to the air soon splits into little cubes, and then melts back into mud again. The spray and mist from the

*See the paper of Mr. Currie referred to in the note on page 143.

falling water, as those who have been in the "Cave of the Winds" beneath the "American Fall" well know, are dashed furiously against the soft shale, and rapidly melt it away, so that a hollow is formed beneath the limestone above, and when the strain on the latter becomes too great it breaks and falls into the gulf below, leaving a perpendicular face behind.

Between 1842 and 1890 the Canadian, or Horseshoe, Fall retreated 220 feet, or at the rate of nearly five feet a year; the "American Fall," whose volume of water is small and breaks in foam from the very top, is only a side fall formed by the shallow channel to the north of Goat Island, a low drift-covered island whose presence in the river alone gives rise to this pretty cataract. This fall has not been long in existence, and will disappear leaving a cliff behind, when the greater fall reaches the head of the rapids above Goat Island, which it is now approaching, for then all the water will flow in the main channel. Such a fate overtook a similar fall on the Canadian side some three miles below this, where the old cataract-cliff still stands telling of what once was. Great masses of rock are piled up at the foot of the American Fall, for there is not enough water to move them, and thus the shale beneath is to a great extent protected from erosion, and consequently the fall is retreating very slightly.

The rate at which the fall retreats and the distance to Lake Erie being known, it seems easy to calculate how long it will be ere this lake will be reached and drained, and also how long the fall has been in crossing from Queenston Heights. But we cannot be sure that conditions of flow of water, and upheaval have always been the same as now, or that they will continue as now; and we do not know what the state of the strata is beneath the remaining miles of the fall's course backwards. No certain calculations can in consequence be made; estimates as to the time occupied by the fall in cutting its present gorge have greatly varied, some giving 7,000 years, and others 70,000 or even more.

A TIDAL FALL. The St. John River enters the harbor through a narrow gorge with perpendicular sides: a rocky ledge, half a mile or so wide, crosses the river just above the gorge, and the water of the river, when the tide in the harbor is out, forms a fierce rapid in passing over the ledge, and pours with a steep descent through the gorge down to the lower level of the harbor. This outward pouring continues till the incoming tide in the harbor reaches the level of the water in the gorge. Then for half an hour, while the level continues, vessels may pass up or down through the gorge, as seen in the engraving (Fig. 107); but as the tide continues to rise in the harbor the incoming volume of water from the Bay of Fundy is so great that it cannot pass up through the gorge as fast as it enters the harbor; the result is that the water below the gorge stands at a great deal higher level than the water above it, and now pours inward through the gorge, reversing the fall and the rapids above as well. This condition continues till with the

Fig. 107. Tidal fall near mouth of St. John River, looking up river; tide at half flood, when water is level in the gorge permitting passage of boats up and down.

change of tide the water in the harbor gradually drops to the level of that above the gorge, when again for half an hour vessels may pass through, till the further dropping off of the water in the harbor again turns the flow outward.

The upward fall in the gorge is highest and the rapids heaviest when, during spring-tides, the river happens to be low; and the outward fall is highest when, during spring-tides, the river is in full flood; for then there is the greatest quantity of water in the river, and the water in the harbor falls to the lowest level. During the seasons of flood in the river the inward fall, even at high water, is very slight, the water in the river backing up almost as fast as the tide in the harbor rises, thus nearly preserving the level. Such a fall as this is seldom seen.

WASTE IN RIVERS.* The amount of waste brought down by rivers, buoyed up and pushed along the bottom, is enormous; estimates, though based on careful experiments, vary considerably but not very materially.

*See Russel's "Rivers of North America," and Geikie's "Text Book of Geology."

Thus the Mississippi, which has been most carefully studied in this particular, brings down to the Gulf of Mexico every year over 406 million tons of waste, or one ton for every 1,500 tons of water; the Po, 76 million tons, or one ton for every 900 tons of water; the Nile, 54 million tons, or one ton for every 2,050 tons of water. It has been estimated that if all the waste of the Mississippi brought down in a year were formed into a column with a base a mile square, the column would be 241 feet high.

But beside this visible waste, there is also a large quantity carried in solution, which the eye does not see. Very many chemical compounds exist in river water; but by far the greatest is calcium carbonate, (the material that forms so much of our limestone,) which constitutes nearly half, the next most important being magnesium carbonate. Of the matter in solution the Mississippi brings down nearly 113 million tons a year; the Nile 17 millions, the Danube nearly 23 millions. Thus the total quantity of material that the Mississippi removes from its basin each year is 519 million tons.

Now, the area of the Mississippi basin is about 1,244,000 square miles, and it has been calculated that the above quantity would cover the whole basin to the depth of about $\frac{1}{4000}$ of a foot. In other words, this river removes one foot of rock material from over all its basin in about 4,000 years, and as this basin has a very varied climate and rainfall, and a great variety of strata, it is thought that this rate of removal is about the average rate of all the rivers of the world combined. The Po, however, removes a foot in 729 years. If then the average height of a country above the sea be known, the length of time required to level it down to the sea may be readily ascertained. Thus if it is true, as has been estimated, that the average height of the land area of the earth above the sea is 2,252 feet, it will require over 9,000,000 years to reduce the land to sea-level. North America is said by some to average 1,888 feet above the sea; it will be reduced to sea-level in something over 7,500,000 years. All this proceeds on the supposition that there is no upward or downward movement of strata going on too.

LAKES.

Earthquakes sometimes, by interfering with the courses of underground streams, cause springs to burst out in new places. The stream that flows from such a spring, in seeking its way to lower levels will meet little depressions,—expanses of land whose outer limits are everywhere higher than the space between. The stream will fill these up till the lowest point in the enclosing rim is reached, when it will again pursue its way. The expanse of water now filling the depression is a lake. In this way practically all lakes have been formed. We see the process going on in miniature during every rain-storm. Lakes are thus closely connected with streams, whether they have outlets or not; they owe their origin to streams, except in the case of delta and oceanic lakes, and it is quite plain that streams will destroy them; for the erosion that goes on in the bed of the outlet, will lower the confining rim of the lake at that spot and gradually draw off the water; if without outlet silt will fill them up. Lakes are therefore not permanent features of a land area as rivers are.

DELTA LAKES. Where new land is being formed,—in marshes, deltas, heads of inlets and elsewhere,—spaces are often seen in which no reeds, water-grasses, etc., are growing; in these the water is deeper than elsewhere; not so much sediment has reached these places as others; and they remain water, as lakes or ponds, when their surroundings have become dry land. Such low-banked, shallow lakes are numerous, especially in the newer parts, in all great deltas, such as those of the Nile, the Ganges, and the Mississippi,—and are to be seen in pond size at the mouth of nearly all our streams where they enter the Lakes. Shallow at best, these expanses of water are only a feature in the building up of flood plains, and seldom remain long without being filled by repeated floodings, or by the inwash from the surrounding land, or by the growth and decay of vegetation.

BLOCKED LAKES. Along many of our streams mill-ponds, which are only little artificial lakes, have been made for the purpose of obtaining water-power. At a narrow spot, immediately above which the stream has low banks with a flat piece of ground beyond them, a dam is

built, and the water, thus checked in its onward flow, spreads out over its low banks and rises higher and higher, till it surmounts the obstacle that man has put in its way, and goes on its road once more. A dam over a mile long, which has produced a lake, has just been completed at Assuan at the first cataract of the Nile. It stores up a vast quantity of the Nile water which would otherwise run to waste, to be used in irrigating millions of acres of land that the desert sand has hitherto blown over. Such dams and for the same purpose, the British authorities in India are building in many places.

Fig. 108. Long Lake, Okanagan, B.C.
Edwards Bros. phot., Vancouver.

What man thus does nature has ever been doing.

The long, narrow, deep lakes that are so frequently met with in mountain regions, especially where elevation is still going on, and that are such an attractive feature in mountain scenery, are to some extent at least the result of this blocking up process. A long mountain valley, as we have seen, may be caused by weathering, by stream erosion, by the scooping-out action of glaciers, by the folding of rising strata, and even by the breaking and sinking of strata.

Such valleys are liable in many ways to be blocked up or formed into basins for lakes. The enormous weight of the mountains bordering the sides of valleys forces the strata in the valley-bottom to give way where weak, and to buckle or bulge upward, producing what is called "warping"; the hollow thus formed will often contain a lake. Lakes formed in this way are very common. They include some of the largest lakes of Europe, Lake Geneva and others in northern Switzerland. Then, too, a more general, though uneven, elevation may raise part of a valley so high that the stream which once ran through it, will seek another course and leave only long lakes behind it. Such is the origin of the Minnewonka lakes (Fig. 62 and pages 133-4), and of many others in the old river courses in Alberta.

Many valleys have been blocked up by glacial drift or moraines; the valley of the Fraser, as we have seen (Fig. 91) was once so blocked, and the narrow lake thus formed has left its mark on the terraces that still border it; but very many of such lakes exist all through the western mountain region, in the Kootenay district among others; several of such are along the line of the Canadian Pacific Railway, Moraine Lake, near Laggan, being one. Such, too, are found in other countries as well; they form many of the "lochs" of Scotland, and the celebrated lakes on the southern slope of the Alpine region in Italy, Como and Maggiore among others; in New Zealand they are met with on as large a scale as they are in Switzerland. In short, wherever glaciers have been these lakes may be found.

Glaciers themselves at times give rise to lakes. In the canton of Valais in Switzerland the strange Mærjelen See is caused by the Aletsch glacier. This great ice-stream in passing down its deeply grooved valley blocks up the mouth of a side valley. The stream in the latter is ponded back and a small lake is formed, which, after lasting from three to five years, is suddenly drained off through cracks or crevices in the obstructing ice, often with disaster to the lower districts, and only the stream is left in the valley. Then again the glacier closes its fissures and the lake gathers once more. This alternate draining and refilling has been going on, it is known, for more than two hundred years. There are many lakes of this kind in Alaska and in

northern British Columbia. "In the Stickine valley near the boundary of Alaska a lake about three miles long and approximately a mile broad, and receiving the drainage of five or six residual glaciers, is held in a lateral valley by Toyatte or Dirt glacier, which flows past its entrance. The outlet of the lake is through a tunnel in this ice which is sometimes enlarged so as suddenly to empty the basin and cause a flood in the Stickine River."* In the Himalayas also glaciers are often seen crossing narrow valleys and ponding back into lakes the streams above them.

Avalanches, too, will thus often block up streams; and when the dam gives way from the pressure of the water behind, great destruction is caused in the lower valleys. Over fifty years ago in a Swiss valley a lake was thus formed; it was of such a size that to avoid destruction of life and ruin of farms and villages, it was determined to tunnel the ice dam near its base and thus gradually drain off the water,—a perilous experiment that was successfully performed.

To former valley-glaciers are due innumerable little lakes of beautiful peacock-blue or green glacier water that are found high up in the mountains at the heads of valleys. These valleys end abruptly with what are called "cirques," almost perpendicular precipices, but scooped or hollowed out into amphitheatre form, the work, in the first place, of several streams that converged here, followed by a glacier that hollowed out the face of the cliffs still more and dug a basin at their foot. The glacier passed away except farther up in the mountains, where it remains only a snow-field which continues to feed the streams now uniting to supply the "lakes and tarns" with their beautiful water. These little lakes are very numerous in the Kootenay district of British Columbia.

The lakes formed by the glacial drift outside the mountains have been often referred to in the preceding pages. (See pages 141-3). In the Archæan area some lie in basins formed wholly of the drift, overflowing at the lowest part of the rim; others lie in depressions in the rocks which were old river-courses of pre-glacial days, but

*Geikie. See also Geological Survey of Canada, Vol. 3, Pt. 1, 1887-8.

now dammed up by the drift, such as the lakes of the Trent valley, Lake Muskoka and those connected with it, or in hollows in the rock dug out by the eroding power of the glacier. Away from the Archæan region the lakes of Ontario, other than the Great Lakes, are all due to the drift, lying either between hills of drift, or in rocky basins one of whose ends is blocked by drift.

In the western prairie region lakes are very numerous; in Alberta and elsewhere where the drift produces a rolling surface, lakes lie among the hills, some of them with no outlet; nearly all are shallow, often drying up in whole or in part during summer. The deeper ones have beautifully clear water and abound in fish. Lake Winnipeg, the fifth in size of all the Great Lakes, varies from twenty to forty feet deep. Along its banks in places the striæ of the glacier are seen entering the water on the east and coming up out of it on the west; the same is true of the lakes along the course of the Albany River,—a circumstance that seems to prove that these large lakes are the work of the scooping-out action of the great glacier. Along the sluggish streams in this region of plain, the rivers are often seen to expand into lake size; the drift is so abundant here that the streams are not strong enough to carry it away. Hence the lakes, whose outlets are often rapids with light gradient.

In volcanic regions flows of lava are often seen lying across streams, thus forming an effectual dam. Lake Yukon on the Yukon River was thus formed. The lava filled the valley of the river several hundred feet deep, damming back the Yukon, and forming the lake. But the river has since cut a deep channel along one side of the dam and regained its old bed below it. Along other river courses in the western mountains the like occurrences took place, though in some cases the old lava has been entirely cut through and the lakes drained. In Iceland several lakes were formed by the fearful outburst of Skaptar-Jökul in 1783. The lava rushed across the streams damming them up, and the water thus checked overflowed the surrounding regions so quickly that great numbers of the inhabitants were overtaken and drowned.

GREAT LAKES. The problem of the origin of the great lakes of the world has not yet been satisfactorily solved. These lakes lie in two great chains, and any theory that accounts for their origin must also account for this remarkable fact. In America the chain beginning with Lake Ontario extends almost to the Arctic, with nearly continuous water connection. It is noticeable that these all lie either at or within the edge of the Archæan area, or just outside of it, as Lakes Ontario and Erie. This fact has given rise to the theory that they are due to the scooping-out action of the great glacier, more especially when it plunged down from the much higher Archæan land upon the soft decayed Palæozoïc rocks below, lifting like an immense dredge a vast load of waste from its bed and depositing it over the drift-strewn regions beyond. All theories, however various, attribute much of the present shape and condition of these lakes to the action of the glacier. This glacier theory cannot account for the great depth of the great Lower Lakes; it seems impossible that the glacier, enormously large as it was, could erode so many hundreds of feet below sea-level; the theory might apply to the shallow Erie, but not to the rest. A subsidence of the ground must here have taken place, or, as some think, those of the lakes the bottom of which extends below the level of the ocean, were once depressions in the sea-floor, like the Caspian and Dead Seas, and the sea-floor, when it was raised, did not go high enough to lift the bottom of the depressions above the level of the sea. Other theories in regard to the five great Lower Lakes have been referred to on pages 134-5, and 143-4.

The other great string of lakes begins with Lake Nyassa in eastern Africa, and passing northward through Lake Tanganyika and others to the north, takes in the strangely formed Red Sea, the Dead Sea and the Caspian, while deep depressions, often containing the beds of dried-up lakes, connect the African lakes with the Red Sea, the north-eastern arm of the Red Sea with the Dead Sea, and the Caspian with the Arctic. Strangely, too, some of these lakes lie below the sea-level; the Caspian Sea is at its surface a little over 85 feet below sea-level, while the Dead Sea is 1308 feet. Some think that there lies a great break or

fault in the earth's crust along this line, and the consequent sinking has given rise to these lakes. The depression exists with its included bodies of water, whatever the cause. (See pages 190, 191.)

LAKE WATER. ~~The water of lakes is most commonly fresh,~~ but in some of the largest lakes in the world, and in multitudes of smaller ones, it is more or less saline or alkaline. It ~~is fresh where the lake has an outlet,~~ it is salt or alkaline where ~~there is no such outlet.~~

As said elsewhere, the water in passing over ordinary ground dissolves from it various chemical bodies, especially sodium, calcium, and magnesium, together with carbon dioxide, chlorine, and other acids; but it remains, as we say, "fresh," unless it may happen, as in the case of some of the little streams in both the Canadian West and in the Great Basin region of the Great Salt Lake in the United States, to run over ground so highly charged with alkali that it becomes tainted. Indeed, it is the presence of dissolved mineral matter in water that gives it its pleasant taste.

FRESH LAKES. A lake parts with water in two ways,—by evaporation, and by streams running from it. Now, if the water that runs into it is greater in amount than what evaporation removes, the lake will find an outlet somewhere; but as evaporation removes only the pure water, leaving behind the chemical compounds,—salt, lime, gypsum, magnesia, soda, etc.,—lake-water must be more impure than the water of the streams that run into the lakes. But the quantity of impurities is very small at best, and the outlets remove some of the impurities left by evaporation, while others become solids and sink to the bottom; then, too, rain falling into the lake, and melted snow flowing from frozen ground, add water with little or none of these impurities in it. In our Great Lakes this evaporation and rainfall nearly balance each other, being about thirty inches. A very great length of time must therefore elapse before such lakes perceptibly lose any of their freshness.

Though this is true yet the total quantity of impurities in lake water is very great. Lake Ontario has an area of

about 7,240 square miles with an average depth of about 300 feet. About 300,000 cubic feet of this water per second, it has been calculated, passes out by the St. Lawrence carrying with it in solution in the neighborhood of $1\frac{1}{2}$ tons of mineral matter, which will amount to about 50 million tons annually. Of this matter lime is by far in the greatest quantity.

Of the great fresh water lakes of the world Lakes Superior, Huron (including Georgian Bay) and Michigan are the largest, having an area of 31,200, 23,800, and 22,450 square miles respectively ; next to these stand the Albert Nyanza in Africa and Lake Baikal in Siberia, with an area, it is estimated, of about 12,000 square miles each.

SALINE LAKES. In seasons of greater rainfall than usual low-lying pieces of land are apt to be flooded and the crop that may be on them destroyed; for either the fields are so flat that there is not enough slope to carry off the surplus water as fast as the rain brings it, or they are lying in a hollow from which the water cannot escape ; so the fields lie under water till the sun dries the water up, or it "soaks away." In some low places where there is no grass or other vegetation, repeated flooding and drying during the summer will leave a white crust or powder on the dried mud, which on being examined will here in Ontario prove to be lime for the most part,—an alkali that has been washed by the rains from the soil into these pools. This is a common sight.

In the comparatively dry regions of the third prairie steppe in the Canadian West, and also in the corresponding regions in the United States, the rainy season forms among the hollows and level places between the hills of drift, lakes from the size of a pond up to hundreds of acres in extent, all shallow and with no outlet. When the season of rain is past and the long, hot, dry season comes, the smaller lakes vanish almost at once, and only a few of the larger ones live on till the next rainy season, as shrunken, unsightly things, half swamp, half mire, and with small expanses of strongly alkaline water, the dried up bottom of both large and small lakes remaining covered with crystals, or even a hard crust, of an alkaline mineral.

These, however, are all small lakes. Others, found for the most part in elevated regions, are very different. In the arid region of the United States, the "Great Basin" as it is called, comprising parts of Utah, Nevada, and Oregon, are found very many and very large saline lakes, Great Salt Lake being the largest. This lake lies at an elevation of a little over 4,200 feet above the sea, and its area, which varies somewhat from year to year, is about 2,000 square miles. Evidence is quite abundant that the lake was in existence when the whole region was much lower than at present. Terraces, too, on the hillsides around the shores of the lake exist at very different heights, as they do in other lakes of the region, which shows that the water in the lake has stood at other and much higher levels than it does now. In the highest of these terraces the shells are those of fresh water shell-fish, so that we must believe that when this terrace was formed the water was fresh; indeed the old outlet leading off toward the Pacific coast is clearly seen.

But the mountains to the west and south-west gradually grew higher,—are doing so still, it is said,—and this caused a drier climate, so that the quantity of water brought into the lake by the streams gradually became less than what was carried off by evaporation; the surface of the lake, consequently, sank below the outlet, remaining stationary for long periods, however, during which new beaches were formed, and then sinking again as the supply of water again slackened. The water now averages scarcely fifty feet in depth, but it is so full of salt that a bather has no difficulty in keeping himself afloat in it,—cannot sink if he wants to;—and where the water runs through the cracks of the platform upon which the dripping bathers stand when coming from their bath, long "icicles" of salt hang in white rows beneath. No fish of any kind, except a small shrimp-like crustacean, inhabit its waters.

There is a pound and a half of mineral matter in solution in every hundred pounds of its water, and of this about eighty per cent. is salt; ordinary sea-water has nearly the same proportion of salt in it as compared with other mineral matter, but it has less than a quarter of the quantity of salt; the other mineral matter of the lake water is mainly compounds of lime and magnesia, with chlorine and sulphuric acid. When during the dry season wide flats are laid bare, a thick hard crust

of salt lies over all, and forms layers and beds of crystals among the mud beneath; and where the water is shallow this crust is strong enough to bear a horse and his rider. In all dry elevated regions such lakes are found; they are very common on the steppes of southern Russia and in the great basin of central Asia.

Some other great salt lakes, the Caspian Sea being the chief, are thought to be remnants of the ocean still filling what were once deep depressions of the ocean's bed. On page 35 reference is made to the sinking and re-elevation of the great area to which the Caspian Sea belongs. In all the region between the Caspian and the Black Seas, and from the Caspian east of the Ural mountains northward to the Arctic Ocean, shells of species of shell-fish now living are everywhere met with; while in the sea itself and the numerous salt lakes of the region, some, like Lake Elton, being quite large, oceanic animals such as the seal and the herring abound, and skeletons of the same are found in the sand of the beds of the old dried up lakes.

Elevation of neighboring land to the height of over two hundred feet cut off the communication with the Arctic Ocean and the Black Sea, and then as the amount of fresh water received from streams and rain was less than what evaporation removed, the Caspian shrank to its present position, eighty-five feet below the ocean-level, where evaporation and inflow about balance each other. The sea (or lake) is of great size; its area is 180,000 square miles, or twenty-five times as large as Lake Ontario and six times as large as Lake Superior; its depth in the southern portion is fully 3,000 feet, but in its northern part, where the sediment from the Ural, Volga and other rivers lodges, it is nowhere more than fifty feet,—to be a great plain at some future period.

The water in the northern part is so fresh as to be drinkable, and in no place in the open sea is it as salt as the water in the ocean; but in the numerous shallow bays along the southern half of the sea east and west the water is intensely saline. In some places only a thin, whitish layer is left on the dried up edges of a pool; in others the shallow water rests upon a bottom of rose-colored crystals of salt; still others have a bottom of thick layers of white salt, and where wholly dried up sand covers strata of salt. One bay, about ninety miles across, called the Karaboghaz, receives its water from the sea through a channel only 150 yards wide and five feet deep. Through this, so great is the evaporation by wind and sun, a strong current continually sets inward at the rate of three miles an hour, bringing in sea-water enough in a day to make 350,000 tons of salt. No animal can live in the intensely salt water of the bay, and no vegetation on its shores: layers of salt intermingled with layers of mud are forming on its bottom, and wherever dry portions of the bottom are met with masses of real rock-salt are found.

Doubtless in Upper Silurian days there was just such a shallow bay where western Ontario now is, in which were formed the salt beds that now give the brine at Goderich and elsewhere, and the gypsum (sulphate of lime) that is found in the same region.

In the neighborhood of the Caspian lies the Aral sea (265 miles long and 145 broad), a shallow lake of brackish water which once was connected with the Caspian, but which has been carried up over 200 feet above it with the rise of the land. The elevation of the region has turned into it the old Oxus and Jaxartes rivers which, in centuries gone by used to find their way to the Caspian along channels clearly seen still, notwithstanding the desert sand. What life exists in it is the same as in the Caspian, and the area between contains the remains of the animal life still found in both.

The Dead Sea (46 miles long and 5 to 9 wide) is one of the most, if not the most, remarkable of salt lakes in the world. It lies in a deep cleft 1308 feet below sea-level, with almost perpendicular rocks on the east averaging 2000 feet high, but on the west strata of limestone and sandstone slope steeply back from the valley, while on both sides the rocks have numerous channels worn in them which lead to the higher ground. Terraces at different levels are numerous all along the hills, the highest being on a level with the waters of the Mediterranean. It is thought by some geologists that a great break or fault occurred here, the rocks on the west sinking down and thus producing the slope on that side. A great basin was thus formed that filled with water from the Jordan and other streams, and had an outlet to the Red Sea; but elevation of the surrounding regions brought a change of climate; it became drier and the lake gradually sank by stages below its outlet till it reached its present level.

The gradual change from fresh to salt water can be traced in the terraces. The upper terraces contain shells of lacustrine shell-fish (those inhabiting fresh-water lakes); these wholly disappear in the lower terraces, no fossils being found there, but in their stead beds of gypsum and of blue clay,—both the product of mineral-charged water; one bed from 30 to 50 feet thick is found in a terrace 600 feet above the present surface of the lake.

The quantities of minerals in solution in the waters of this lake are somewhat less than in the Karaboghaz, but greater by two-thirds than in the Great Salt Lake, and seven times greater than in ocean water; but the proportion of salt (chloride of sodium) among these dissolved minerals is three times greater in the water of the ocean and of the Karaboghaz than in those of the Dead Sea water. The reason of this is that the waters of the Dead Sea contain a very large quantity of chloride of magnesium (about 146 parts in 1000), and this will not allow

much salt to remain in solution in the water but causes it to fall to the bottom (precipitates it) where it forms layers of solid salt ; it precipitates the gypsum also ; the Great Salt Lake has only about fifteen parts of the chloride of magnesium in a thousand and so the water is far salter. In the same way the presence of carbonate of sodium in considerable quantities causes carbonate of calcium (lime) to be precipitated. When sea-water has lost thirty-seven per cent. of its water by evaporation gypsum is precipitated, but not until a much larger per cent. of water has passed off is salt precipitated. This is why gypsum is found underlying beds of salt.

CRATER LAKES. Fig. 69 represents a kind of lake by no means uncommon in volcanic regions, a lake occupying the crater of a dormant or an extinct volcano. The eruption has not broken through the walls of the crater, and the pit thus left has been more or less filled by water percolating into it from the surrounding higher ground. Sometimes these lakes, such as Crater Lake in Oregon and Lago di Bolsena in Italy, are so large that it is supposed they occupy the site of what was formerly a mountain ; some fearful eruption has blown away the upper part of the mountain, as was the case with Krakatoa in 1883, leaving only a huge gulf, or else the internal heat has been so great as to melt the rocks, and the whole upper part of the mountain has thus fallen in and disappeared. Crater Lake is from five to six miles in diameter, and 2000 feet deep, the cliffs rising from 900 to 2200 feet above the water. The Lago di Bolsena is over ten miles long and nine miles wide.

Such lakes are found in New Zealand and India, and are especially abundant in the extinct volcanic region of south-central France. Sometimes, as in the Souffrière, the water is warm, even hot, but it is usually cold ; and very commonly, as might be expected, it is alkaline, as are the famous Soda Lakes in the Great Basin.

"Ox-Bow" lakes have been referred to under "Meandering of Rivers," page 166.

DESTRUCTION OF LAKES. Incidentally the means by which lakes may be destroyed has already been referred to : the obstruction by which the water of a river has been thrown back, has at last been cut through by the outflowing stream, and the water of the lake has been thereby drawn off,—just as flood plains have been

turned into terraces. But as the water of such outlets has very little sediment in it and so cannot erode very fast, long before the lake can be thus drained, the sediment from the inflowing streams, and what has been worn from the banks by the action of the waves, will have spread a thick deposit over the bottom of the lake, which, at the points where the streams enter, will have risen to the surface as a delta; the delta will have steadily advanced, filling the lake from side to side, till, it may be, that alluvial deposit alone will have destroyed the lake before its surface has been perceptibly lowered by draining. Such seems to be the fate in store for the shallow Lake St. Clair, for Lake Winnipeg, for Lake Geneva, and many another.

Of Lake Geneva Sir Chas. Lyell says: "This sheet of water is about thirty-seven miles long and from two to eight broad, varying in depth from twenty to one hundred and sixty fathoms. The Rhone where it enters at the upper end is turbid, but where it issues at the town of Geneva, it is beautifully clear. The ancient town of Vallais once situate at the water's edge, is now more than a mile and a half inland, the intervening tract of alluvial land having been acquired within the last eight centuries. The rest of the delta is an alluvial flat, five or six miles long, rising a little above the level of the lake and full of marshes. . . . If we could obtain a section of the accumulations formed in the last eight centuries, we should see a great series of strata from 600 to 900 feet thick and nearly two miles in length inclined at a very slight angle. . . . A much greater deposit, belonging to times preceding the historical, would be seen extending from this to the original head of the lake five or six miles distant."

Should this lake fill up before the outlet is cut down, the Rhone will have a winding course through the new plain, and being highly charged with sediment will rapidly cut down the old outlet, and the channel through the plain deepening at the same time, the plain will be left as terraces, to be slowly washed down into the river again, and recommence its journey to the Mediterranean.

Our Great Lakes are not filling up fast; for though there are very many streams entering them yet they are all small and for the most part come from the Archæan area the rock of which is not easy to erode, and therefore the streams have but little sediment in them. Besides, the St. Lawrence in trying by deepening its channel to drain Lake Ontario, has an impossible task before it,—the bed of the lake lies, as we have seen, below sea-level. So that, even

if there is no change in the earth's crust here, when the river gets down to base-level there will still be a lake, though a much smaller one, where the present great lake lies. Yet it is quite easy to see that when this stage is reached, the little lake must soon fill up ; for now it will be everywhere bordered by broad deep alluvial terraces in which the streams will cut deep gashes that the rains will readily widen into broad flaring valleys, the sediment dropping to the bottom of the lake.

But before the St. Lawrence can do this, the Niagara Falls, which, as we have seen, is moving towards Lake Erie seven miles away, at the rate of four or five feet a

Fig. 109. Glacial terraces, Dundas valley.

year, will have reached that lake and drained off all its shallow water down to the very bottom ; and now the old "Erian" river will flow in its old channel again, but will pass into its old "Ontario" basin by the new Niagara channel, not by the old "Dundas valley" channel; and it, too, will carry a heavy load of sediment from its soft alluvial bed and deeply trenched terraced borders into the shrunken Ontario Lake. The story of the destruction of one lake will be, with little variation, the story of another, and the terraces around the old basin of Lake Erie will tell how high the water once stood, where it paused, and how it dropped off again, just as the terraces around Dundas valley tell how high Lake Iroquois rose, and how its water dropped off stage by stage.

We see how a lake must write a record of its life upon the shores that surround it. We know that beaches line our lakes almost everywhere, and when the water in the lake is low, the beaches are broader than at other times. Some of these beaches, after dropping off beneath the water with a very gentle slope, suddenly dip steeply downward; should the lake fall these flat reaches above the steep dip will be the terraces or the benches, and will mark the height to which the water once attained and where it lingered a long time.

But these terraces will show much more. Everyone who has loitered along the beaches of our lakes, has seen dead fish lying on the shingle, or even seen living ones coming to the edge of the water and allowing themselves to be thrown upon the pebbles by the lapping wavelets,—fishes, that, if thrown back by a pitying hand into the water, will soon be seen on the pebbles again, returning to die. Shells, too, of various kinds will here be seen, often in abundance, especially where streams enter the lake, some of them land shells, and other evidences of the life in or around the lake will also have been met with. Some of these remains get buried beneath the beach material by the lap of the waves, or get covered up by the sediment beneath the water; and in future years, after the lakes have passed away, the explorers of these benches and terraces will be able to tell the kind of living creatures that inhabited the waters of the lake or lived along its shores.

The little lakes that occupy the cirques spoken of on page 184, are blocked mainly by waste brought down by the converging torrents; they, too, are forming little plains beneath their waters, and they, too, will at no distant date be drained away, though others may form elsewhere. Such little abandoned lake-bottoms are common in the western mountain regions; they seem to be especially so in Colorado and on a somewhat large scale, where they go by the name of "parks."

FILLING OF GLACIAL LAKES. The drift-covered area is full of swamps and bogs and "muskegs" across which it is always difficult, and often impossible, to make one's way: the ground shakes beneath the feet, and when it breaks a black oozy mass bursts forth from an

unknown depth,—a mass that like the firmer covering will be found when dried to burn readily, though not with flame. In most instances, though not in all, these spots were once occupied by small lakes. Not much sediment could reach them except what was blown in by the wind; but they have been filled up almost wholly by vegetable growth. Trees that grew round their borders fell into them and finally sank; lilies and grasses and ferns and other water-loving plants grew around their edges and died there, slowly accumulating into decayed masses and extending thereby the shore outwards into the lake.

Fig. 110. A glacial lake almost filled in. In the left background the peat is firm and is covered with spruce and fir trees: growth of the peat is inward from the foreground. Here it is too soft to bear a man's weight.

But the chief agent in producing the black mass that finally filled the lake was *sphagnum*, a kind of moss whose peculiar property is, that while the lower part is decaying the upper is growing and vigorous. The sphagnum grows from the shore outwards and spreads out over the water, floating and growing there, while its decaying under part is continually falling to the bottom. In time the lake becomes wholly covered with the sphagnum, and the mass beneath is a black liquid mud; it is a muskeg, the most dangerous condition for whatever attempts to walk across it.

In the meantime near shore the whole mass has become firmer, the top part is a tough body of interlaced roots of the moss and quite spongy; but below, the material is fine and black, turning brown when dry, but where taken from a considerable depth it keeps its black color, is very fine in grain, and when dry breaks into little hard black cubes;—it is imperfect coal. Trees and shrubs will creep in on the

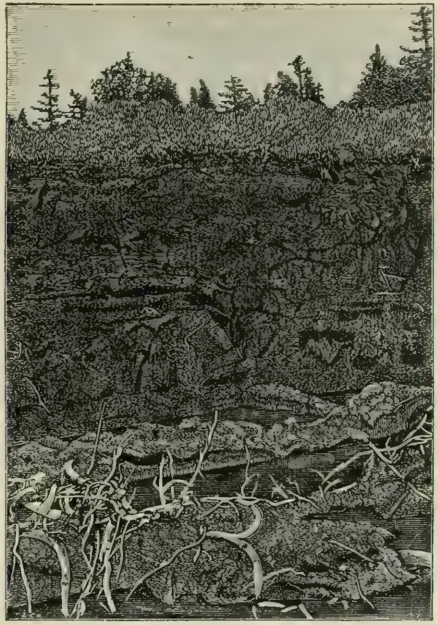

Fig. 111. Peat pit, Rockwood Park, St. John, N.B.; pit 10 feet deep, the peat extending over 20 feet deeper.

newly-formed ground and by their decay help to make all more solid, but leaving leaves and roots and branches buried in the mass where they may remain for long centuries perfectly sound. Black walnut has been dug up from a swamp in Kent county and manufactured into furniture; pine similarly obtained has been cut into boards. Searching bogs for logs is an industry in Delaware and farther

south. All over our northern regions this peat is found filling up old lakes; and in northern Europe, where it is extensively used as fuel, an abandoned peat basin soon fills up again. It is abundant in all parts of Canada, though it has not yet come into use to any extent as a fuel.

DESTRUCTION OF SALINE LAKES. With saline lakes the question of disappearance is different; they have no outlet and cannot therefore be drained; if they disappear they must do so by evaporation, and the old beds of such are numerous in arid regions. But the sources from which these got their water must have been cut off by some earth-movement, or some change of climate, as was the case with those in the Great Basin in the United States; otherwise such lakes could not well disappear. The smaller ones may indeed be filled up by sediment and saline and alkaline deposits and thus become marshes, such as exist in the arid regions of the United States, of Asia, and northern Africa; but this would be scarcely possible with the larger ones. If the evaporation at present is greater than the inflow, such lakes are shrinking, as is apparently the case with the Aral Sea, and will do so till the two are equal.

But this is not all. Deposition of river sediment and of chemical compounds must be filling up the lakes. The Volga and other rivers bring great quantities of sediment into the Caspian; this is deposited at the northern end, but as time goes on it must extend farther and farther south. The inflow and evaporation are said to be about equal; if so the sea at the south must be getting deeper and broader in proportion as it is getting shallower at the north. But the sediment must at last invade and fill up the south end too; then the rising water will find an outlet westward and will make a new course for itself and the Caspian will become fresh, to be ultimately drained by its new-made outlet. But what geologic or climatic changes may not take place before then?

IMPORTANCE OF LAKES. The presence of large bodies of water affects the climate of the neighboring regions, for water cools less rapidly than land, and becomes heated less rapidly. Lakes thus serve to modify the heat of summer and the cold of winter. This is a well known fact in the region of the Great Lakes in Canada.

Lakes, as we have seen too, serve as settling basins for the water of rivers; the sediment held in suspense (not in solution) settles to the bottom and gradually fills up the lake, where the deposits may be very thick, since some lakes are very deep. So it is seen that when water entering a lake is muddy, it passes out again clear and blue.

Then on rivers where lakes exist there are no great floods; the great basins receive the surplus water of the flooded streams and store it up, letting it pass off gradually and not with a sudden rush. In some streams without lakes a "break-up" in spring causes a very rapid and destructive rise in the water; this never occurs on the St. Lawrence.

Lakes have an animal and a vegetable life of their own, differing from those of the sea; they thus extend the wonderful variety which we see in the world of life around us. Many of the varieties of fish inhabiting our lakes the sportsman may seek for in vain in the sea,—the white-fish, the maskalunge, the black-bass, and others. The strata that form in lakes will preserve the fossils not only of the life both animal and vegetable that belongs to their waters, but also of the life that belongs to the land around them.

OLD LAKES. Existing lakes have all had their origin in the later ages of the world, yet we know that former ages had their lakes too; some of these were of vast extent, for in them were formed the strata of Mesozoïc days (pages 32-34), which have kept for us the fossils of the terrible Deinosaurs; other fossils still of plants and animals show us that these lakes were fresh. And we have seen that a great lake, Lake Agassiz (page 42), lay where the Red River valley now is, and that still others, due to the ice sheet, covered a large part of what is now dry Ontario land, together with our present Great Lakes. The terraces tell this tale.

UNDERGROUND WATERS.

SPRINGS. We have seen that the rain which falls upon the surface of the ground, in part runs off to form streams, and in part sinks into the soil; some of the latter is evaporated, some taken up by roots of plants, and some continues its progress downward to the beds of rock or clay lying beneath. If the rock is of a loose, porous nature, such as sandstone, the water will fill its pores and saturate it, going down as far as the rock itself goes; but

if the rock is close-grained and hard, or if a bed of clay is met with, the water will filter slowly along it, following whatever slope it takes, and should the beds come to the surface at the bottom or on the side of a hill, springs will be formed all along them. Along Scarboro Heights the upper beds are of sand or drift, below which is a bed of somewhat stiff clay. Wherever this bed appears along the face of the cliff springs are found. Some of the summer-residents near by go down the cliff sixty or eighty feet to springs for their household water; and, strange to say, little swamps exist on the face of the cliff almost where the cliffs are steepest, in which grow "cat-tails" and many other water-loving plants. Galt is supplied with water from springs in the limestone that underlies the deep masses of drift in that region.

Fig. 112. Upturned, shattered and weathered strata, covered with loose material from weathering. The rain will enter the fissures and follow them downward. The low ground in the neighbourhood of this hill is always wet. St. John, N.B. (west side).

Where the bed-rock is jointed, as is the case with limestone, and lying in nearly horizontal beds, the water will work its way both horizontally and downwards, taking advantage of any faults or breaks of any kind that may occur; and should these beds crop out, as they do so commonly on mountain sides, springs will be the result. This is why springs are so numerous on mountain-sides. The water in wells dug in alluvial plains or porous rock near rivers, varies in depth according as the depth of the water in the rivers varies,—full when the river is full, low

when the river is low. The water of such wells comes from the river.

When springs burst up in low ground, the cause is practically the same as elsewhere. The water must come from a higher source or else it could not "boil" up as we see it do. But it has followed down to an unknown depth the rents and bedding-joints of upturned strata, such as are shown in Fig. 112, and then, meeting a fault or fissure, or still following the bedding-joints, which may have received an upward curve, it has reappeared at the surface of the low-lying valley as a spring. For the water which fills the pores and crevices of the rock on the higher ground, exerts great pressure upon that which is in the rocks far below, and thus forces it upwards. Of course the pressure is not nearly so great as it would be, if the water that fills the rock had larger openings than pores to pass through; but the pressure is still great. The water of such springs as these may come from a very distant region (Fig. 113); and it is water which has thus penetrated far into the ground that is such a source of danger in deep mines: at any moment an underground reservoir of water may be tapped and the mine flooded.

ARTESIAN WELLS. These facts explain artesian wells. The rain that falls upon soil whose underlying strata are tilted and fractured like those represented in Fig. 112, must penetrate to a very great depth. If such rocks as these,—and they cover a wide area in southern New Brunswick,—should be overlaid by others so hard and compact that water cannot penetrate them, there will be no chance of escape upwards for the water, but it will be confined under very great pressure hundreds or thousands of feet below the surface, and far remote from the region where it first entered the ground. Now, should a hole be bored down through the overlying compact rock, till it reaches this water-filled stratum, it will give a means of escape to the water, which, though not always reaching the top, will usually fill the hole and flow out, sometimes as a jet rising many feet in air. In southern England and northern France the borings for artesian wells go downward through strata of different kinds till they reach the

soft, porous water-filled chalk, which underlies the upper strata in both countries and comes to the surface in the neighbourhood of the English Channel.

The very great importance of such wells as these to dry regions is very readily seen. At the present day, when the regions with a sufficient rainfall are largely occupied, attention is being turned to the drier and less desirable regions, and the geological formation of the surrounding districts of abundant rain, often hundreds of miles away, is carefully examined. The structure of the rocks and the direction of the dip of the beds are observed, and if they are found to be "water-bearing" rocks and dip towards the dry region, artesian wells are sunk in the latter. It was by this careful examination that the French government was led to sink such multitudes of these wells in southern Algeria and the adjoining desert, which have wrought so great a change there, creating fertile fields over wide areas where formerly was only sand or at best a scattered and parched vegetation. Such wells, too, are now very numerous in the dry regions of California,

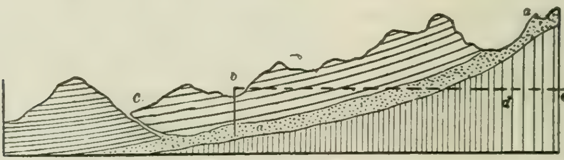

Fig. 113. Spring and artesian well: *aa* a bed of porous rock exposed on surface at one end much above the other end, and lying between two beds of hard rock; *c* a fissure leading down to porous bed and forming a spring; *b* a boring down to the porous bed forming an artesian well.

where whole fruit farms are entirely dependent on them for water. On the dry eastern approaches to the Rocky Mountains in the United States and in Canada, they are also numerous, and must be far more so in the near future.

Artesian wells have become a necessity in our modern world, not only for the purpose of irrigating land that would otherwise be valueless, but for supplying pure water in thickly settled countries, where the surface water is rapidly becoming too impure for drinking, and where aqueducts bringing water from gathering-grounds in mountain districts, would be too large or too expensive to construct or maintain. Winnipeg in Canada and many towns elsewhere are already supplied with water from artesian wells. Some of the artesian wells are very deep; one at Berlin in Prussia is 4,172 feet deep, one at St. Louis, Missouri, is 3,843 feet deep, while others have gone beyond 5,000 feet.

The famous oases of the Sahara and other deserts are only patches of vegetation that spring up around a "natural" artesian well, such as is represented at (*c*) in Fig. 113. Unfortunately, the water of some of these oases wells, though it may support vegetation to some extent,

is not drinkable, for in its journey to these vents the water has to pass through strata of salt or of some alkali with which, as we have seen, the dried up bottoms of lakes or seas abound.

37 **HOT SPRINGS.** Sometimes the water penetrates so far downward that it reaches the part of the earth's crust where the temperature is high. It will then on returning to the surface give rise to hot springs, varying in temperature up to the boiling point. The hot springs of Banff have a temperature of 114.3°; those of Bath, England, 120°; others in volcanic regions reach the boiling point; this last is especially true of a volcanic region in New Zealand. Here these springs have shaped for themselves little mineral-lined basins like bath-tubs, in which the Maoris delight to sit, changing from them to cold ones which, strange to say, exist here literally side by side with the hot ones. Indeed, at Banff bathers might almost enjoy the same luxury, for here, too, the hot springs, fed from a depth of thousands of feet in the earth, exist almost side by side with cold springs fed by melting ice thousands of feet overhead. A little knowledge of the earth's crust, its rocks, their kinds and their bedding, makes this extraordinary fact a very simple one.

MINERAL SPRINGS. But springs, and especially hot springs, do more than bring water to the surface of the ground. The water dissolves the rock through which it forces its way, and commonly deposits a portion at least of what it has dissolved, around the spot where it issues from the ground. As might be expected, the deposited matter is very various, but consists for the most part of sulphates and carbonates of calcium, magnesium and sodium, chloride of sodium, with silica (which usually completely petrifies the wood or plants that the water flows over), iron, and traces of others.

The beds thus deposited are sometimes very extensive. The hot baths of San Filippo in Italy have built up a hill 250 feet high, a mile and a quarter long, and a third of a mile wide. There and elsewhere this material is used as building-stone. But only a very small proportion of the dissolved material is redeposited by the water of any spring; the rest

passes off into the streams. Hot springs that contain silicates, deposit a good deal of their silica around the vent as the water cools, and hence thick beds of the material called "sinter," a silicate, are met with in the western mountains of Canada and the United States, especially in Yellowstone Park. The "petrifying" springs found in many places, cover stones, twigs, etc., around them with a limy deposit, as the silicate springs do with silica; the sulphur springs of Preston, Paris and other places, deposit a thin coat of sulphur where their discharge flows away, but those of Caledonia Springs, even where the sulphur is present in large quantities, deposit nothing.

The water of sulphur springs is thought by many to come from a great depth, and to have been warm when it came in contact with the sulphur-bearing rocks, becoming cool in its passage upwards. If this is true, the water of the sulphur-springs of Ontario must come from deep down in the Archæan rocks, which underlie, as we know, our sulphur-bearing limestones; for there is no evidence to show that these limestones are anywhere much over a thousand feet thick,—which does not bring them down to the heated portion of the earth's crust.

Springs whose water contains iron,—"chalybeate" springs,—are very common; and as iron readily unites with the oxygen of the air, the streams flowing from these springs deposit large quantities of the brownish yellow oxide of iron along their beds and sides.

Brine springs owe their origin to water passing through deposits of rock-salt, or porous rocks that contain salt. Some of these in Cheshire, England, are known to have been flowing for over a thousand years; and from their size they must carry great quantities of salt to the rivers. Indeed in very many places in Cheshire so great has been the removal of the salt from beneath the surface, that large tracts of land have settled down many feet below the general level and have thus become lakes. Salt springs occur in many countries, and as in Western Ontario, are usually the seat of salt industries.

If the origin of petroleum is the decayed bodies of the animals of early geologic periods and eras of the world, (page 6), then it is not a matter of wonder that petroleum

springs are found the world over. Sometimes only little globules of oil rise through the water and float on the surface of the springs, sometimes the whole surface is oil. Along the Athabasca River in the Canadian Northwest, the lofty banks in many places consist of "tar-sands," loose material from which oozes a dark, thick liquid, that is evidently partially evaporated petroleum. Asphalt, which is regarded as the evaporated and hardened remainder of petroleum, occurs in many places in masses,—in Mesapotamia, around the Dead Sea, in Burmah, and elsewhere; but the most remarkable deposit of asphalt is the famous "Asphalt Lake" in the island of Trinidad, which covers an area of ninety square acres. The asphalt is quarried as material for roads, and for other purposes.

Some springs emit gas; all contain more or less carbon dioxide, which often shows itself in bubbles rising through the water; some give off sulphuretted hydrogen, and in places "natural gas" springs are met with, the gas in some being in sufficient quantity to burn for a short time when lighted.

UNDERGROUND STREAMS; CAVERNS. We have seen how hot springs are formed, and that their waters are charged with mineral matter which they hold in solution. This mineral matter must come from the ground and be gathered from the rock through which the water passes. Now, unless the place of this rock which has been so dissolved away, is taken by other rock, vacant places,—hollows, channels, caves,—must be thereby formed in the rocks; in other words, watercourses beneath the ground must of necessity exist. And as we have seen that limestone is more readily dissolved than any other rock, it is in limestone regions that such passages are most numerous. Near the upper end of the Minnewonka Lakes a stream of water is seen pouring from a hole in the mountain-side about thirty feet above the level of the lake; and at a point along the Canadian Pacific Railway at "Hole in the Wall" Mountain, a cavern appears in the face of a high cliff; at the bottom of the cavern is a little pond whose overflow escapes as a stream farther down the mountain. Quite peculiar is the Maligne River, a deep and strong tributary of the Athabasca in Alberta. About two

miles away from the Athabasca it passes through a gorge from 50 to 100 feet deep, and from 15 to 20 feet wide. The walls of the chasm have almost closed over again at top since the river cut the gorge, only a few small boulders caught in the crevice apparently preventing it. But just above this gorge the volume of water is only one eighth of what it is below, so that part of the water must run through an underground channel, or more than one, to join the other below the gorge. "Medicine Lake, drained by this stream, is eleven miles distant, and it is reported that the greater part of the water flows all the way by an underground passage, only the excess of water in flood-time and that of the small tributary streams being on the surface."

Often in boring artesian wells the drill suddenly drops down several feet and an uprush of water immediately follows. At the city of Tours in France, when the drill had got through the chalk at a depth of 364 feet, a rush of water followed bringing up land shells, pieces of wood, and marsh plants with their seeds and roots, such as were found in a valley in the mountains of Auvergne 150 miles away. Small fishes, too, have been thrown up by the first outburst of water, as was the case in several instances where the French were boring wells in the Sahara; they came from a depth of 175 feet and were identical with fish living in ponds and lakes a very great distance from the wells. They were perfect in all their parts, not blind as are the fish in the Mammoth Cave and others. These and many other facts show that beneath the surface of the ground there exist reservoirs and streams of water that are connected with the surface waters by openings large enough to take in the objects mentioned.

The caverns through which these streams flow,—and only those whose floor is not below the level of the bottom of neighboring valleys, are known,—must, where rain and vegetation are abundant, in time become very large. Naturally, too, their course will be very irregular, and falls and expansions will occur just as along the course of surface streams. One of the greatest caverns known, which is at the same time a water-course, is the Mammoth Cave in Kentucky. It is in limestone, but overhead the roof is of sandstone, which is far less liable to be dissolved by

water than is limestone. Side streams flow into this cave, and it has branches running off in different directions, and miniature lakes and waterfalls. The main stream comes out in a large spring in the neighboring valley.

The Wyandotte Cave, in Indiana, another famous cavern, has a length of over four miles, and has one gallery 210 feet long, 90 feet wide, and 65 feet high.

Not all caverns formed by water have streams in them; the water passes off otherwise. Commonly the water trickling through the roof deposits long "icicles," *stalactites*, of mineral matter, the dripping from which forms beds or conical heaps, *stalagmites*, on the floor; the two often fill up the cave in part with most fantastic and beautiful forms; sometimes, in dry regions especially, the whole cave is filled.

The roofs of the caverns that this constant dissolving away forms, often fall in, as will doubtless be the case with the Maligne River caverns; it is then that their existence is discovered. Sometimes only holes in the roof are formed, and these serve as passages through which the surface water falls immediately into the stream below, carrying with it objects of various kinds,—plants and land shells especially,—and also the wash of the ground (which materially helps in eroding the cavern), so that circular depressions called "sink-holes" or "swallows" are soon formed. Sometimes, too, where the cavern is large, the falling in of the roof forms a short ravine; in places this ravine may still be spanned by an unfallen portion, giving rise to a "natural bridge," — of which the celebrated "Natural Bridge" in Virginia is one of the best known examples. But these "bridges" occur all over the world and are often met with in the limestone mountains of the Canadian West.

The streams that may continue to pass along these new-made ravines will, of course, issue from a cavern and pass into a cavern again, or a swallow. Many of the rivers of Greece, believed to be rivers of Hades, were streams that plunged into caverns sometimes to reappear at a distance, sometimes not. Lake Copaïs in Bæotia was

drained by a river that lost itself in a cavern. The poet Coleridge tells us in "Kubla Khan" how

> ". . Alph, the sacred river, ran
> Through caverns measureless to man,
> Down to a sunless sea."

GLACIERS.

In winter during a heavy snow-storm, the snow is often piled deep on our roofs so that it slips from its position and falls to the ground. But it does not always fall. Then as days pass by, it is seen slowly to leave the upper part of the roof, and becoming more and more like ice as it does so, at last clings, a mass of solid ice, around and under eave-troughs, projecting slates, or shingles, tearing the first from their fastenings and breaking the others, and then, slipping from its place, brings all to the ground with it.

The mountains,—the roofs of the earth,—are the great gathering grounds for the snow. Here the peaks and plateaus that rise above the snow line—a height above the sea of 18,000 or 19,000 feet in the tropics, but gradually falling to sea-level in the Arctic regions,—are all the year round covered with snow, and where the moisture in the air is very abundant, as it is on the southern coast of Alaska, in the Alps, in New Zealand, in southern Chili, and in many places in the Himalayas, the fall is heavy, and the snow lies deep. Sometimes it piles up so deep on steep mountain sides, and overhangs crags in such great treacherous wreaths, that a step, or a jar in the air caused by the discharge of a gun or even, it is said, the sound of a voice, will send huge masses of snow and rock in avalanches far down into the valley below, often with disastrous results to life and property.

FORMING GLACIERS.

But it is not by avalanches that the tops of mountains and plateaus above the snow-line are relieved of their snow, nor does snow go on piling itself up forever deeper there, however much the poet's "three silent pinnacles of *aged snow*" may suggest it. Snow, it must be remembered, is only countless multitudes of delicate little crystals of ice, whose star-like rays make them cling together in light, fluffy clusters as they fall to earth. But when they lie in deep masses on the ground they "settle,"—their weight forces the crystals more closely together, and the pressure increases as the depth of the snow increases. Through this pressure the snow, especially in the lower layers, is in a measure melted, becoming thereby a somewhat loose granular mass resembling fine hail and snow frozen together, usually called "névé."

But the weight of the snow in this solidifying work is helped by the sun, which even up here has considerable power. The mountain traveller and explorer, Whymper, found huge icicles hanging from the cliffs of Chimborazo far above the snow line; and we have all seen, even in the most bitterly cold days of winter, how a thin glaze of ice will cover over a sheltered spot on the side of a snow-bank facing the south. The sun, when the frost is off its guard, suddenly melts the upper layer of snow, which is at once frozen into ice; but this thin layer of ice keeps the cold winds from the snow underneath, and allows the rays of the sun to pass through and melt the snow into a little cavity, which, when the sun is gone, is found to be lined with a layer of granular ice, sometimes two or three inches thick, or even the whole mass below has become so changed. The same thing without doubt occurs in the snow on the mountains and plateaus, thus materially helping to form the névé.

GLACIER MOTION. This is not all, however. The icy mass is not confined to the high plateaus and mountain peaks where it is formed. It stretches from the snow-fields of the névé in long arms or streams down through the valleys, and sometimes into the low-lying ground, where the climate is as warm as in southern Ontario. The ice could not have formed in these lower valleys; all the snow that falls on the hillsides there melts in the spring as it does with us. In fact long ago it was suspected that somehow this ice came from the snow-fields far up in the mountains, working its way down to the plains at their feet where it melted as fast as it came forward. It was seen that a block of stone lying on the ice would to-day be directly opposite a boulder on the side of the mountain near the edge of the ice, and that to-morrow it would be a little way below the boulder,—two or three feet farther down the valley. Then in some years the end, or nose, of the ice would be farther out of the valley than others. These and many more things noticed about the ice-stream led to the belief that it moved.

About 1840 some scientific men carefully examined these ice-streams, or "glaciers," in Switzerland. In order to

prove that they move, a row of stakes was set up straight across one of them, the Mer de Glace of Chamouni, and before many hours the straight line of stakes had become a regular curve, the stakes on the central part of the glacier being farthest down the ice-stream. This proved not only that the ice moves but that the central part moves faster than the sides. Since then this experiment has been repeated in various places and in various ways with the very same result, only in some cases the downward curve was much sharper than in others; in other words that glaciers differ in the rate at which they move. Similar experiments have been made on the side of a glacier, where suitable opportunity offered, which have showed that the upper parts of the glacier move faster than those below.

What a singular state of things these two facts show us regarding a glacier! An infinite number of inconceivably thin sheets of ice standing on edge, gliding past, or falling behind each other, and cut by, or cutting, an infinite number of like thin sheets lying horizontally, these, too, gliding past or falling behind each other! How does the ice do it? That it is done, is certain. Water, too, does it, as we have seen, and the appearance of the rocks shows that even the hard rocky strata do it.

Moreover we know that glaciers move through winding valleys just as well as through straight ones, but in doing so the place of quickest motion is near the hollow of the curves, as is the case with rivers; then, a glacier that may be a mile or more broad is seen to contract and pass through a gorge only a few hundred yards wide, and spread out again when the valley becomes broader. The Great Glacier of the Stikine in British Columbia, after passing through a gorge about half a mile wide, enters the broad valley of the river at right angles to it, and there expands, fan-shaped, to a width of nearly four miles.*

As the compressed glacier passes through a gorge the ice tends to break into a very rough tumultuous mass, just as the water in a river does in passing through a similar narrowed channel. In places the top of the glacier curves downward more or less steeply, and here wide gaps and chasms, called "crevasses," open in the ice, and the ice often seems to stand in great pillars or isolated masses. These crevasses, when a row of them extends across the

*Curiously enough, the nose of this glacier approaches to within a few rods of a hot spring that bursts up from the bottom of the same valley.

glacier, form a curve, the hollow looking down the glacier, but the edges of each crevasse are, on the whole, straight. The glacier in such places is passing over a sudden dip in its bed;—it becomes an "ice-fall" or "ice rapid"; and the strain, or force, that produces the crevasses, is the endeavor of the glacier to move faster over these steep places. The direction of each crevasse is at right angles to the strain that causes it. (Cf. page 110.)

When the fall or the gorge is past, the broken and roughened ice becomes smooth again, and the crevasses usually close,—in both movements like the water.

Sometimes a point or shoulder of rock will project from the side of the glacier-filled valley a little way out into the ice-stream; here in the little cove, or bay, or eddy thus formed, the ice seems to move just as water does, for a slab of it shows a beautifully curved and wavy ribbon-like structure, just as if the whole mass of ice caught behind the rock had been set in circular, wavy motion by the pressure or friction of the mass that was freely moving onward farther out. We can readily see this motion in the case of the more quickly moving water; the same motion must take place in rocks too, when they are undergoing great pressure, for the same appearances are presented in them as in ice under pressure. Indeed, the behavior of a field of thick floating ice when it meets with an obstruction to its free movement, well illustrates the behavior of rocky strata when in motion by pressure from behind: the ice breaks into cakes, some of which are shoved over others, some pushed below, others standing on end, still others piled in wild confusion, while here and there is a mass that keeps its level position. (Cf. Fig. 95 and pages 80-86.)

CAUSES OF GLACIER MOTION. Scientific men are not yet agreed as to what causes some of the glacier motions, or as to the manner in which some of the causes act, especially how stiff ice can go around curves, divide above an "island" and unite below, or compress into a gorge and expand below it.

On the high gathering grounds while the snow is being compressed, and while still in its névé state, its great weight forces tbe loose granular mass outward, just as a

heavy weight placed on a heap of apples will force the apples to spread out. Now, if the gathering ground is, on the whole, level, the icy mass will be sent down the sloping sides all around the plateau, and naturally it will take to the valleys that lead down to lower ground, as is very evident from a glance at the map of the Illecillewaet snow-field (Fig. 116). But if the snow-field is on sloping ground the névé will, of course, move only down the slope. But in thus moving off it very soon becomes solid ice.

How can this solid ice continue its motion? We know that it does move. It was formerly thought that the ice just slid down the mountain valleys,—that is, that attraction of gravitation is the cause of the movement. But in very many cases the slope is too slight for this; yet where the slope is steep and the bottom and sides of the valley are worn smooth, some of the motion must be due to sliding. Still, the glacier does not stop when it comes to a narrow channel or to a mass of rock in its path, as it would do if this sliding motion were all.

Then, it was observed that the surface of the glacier has many small cracks in it beside the crevasses, and that the sun, especially in summer, forms on the ice rills of water which fill these cracks and crevasses and the pores of the ice too; at night this water freezes, and in doing so expands, exerting at the same time an enormous force, or energy, which drives the ice in the direction of least resistance, viz., down the valley; just as along the shores of our lakes in winter, when the ice breaks in long cracks, the water rises in the cracks and freezes there, thereby forcing the ice up the beach, a roll of pebbles and sand before it; till through repeated action of this kind a long mound of beach material is built up, which is often mistaken for a terrace. But then on the glaciers this freezing extends at best only a little below the surface, and, if the theory were true, the ice would move faster in the evening when the freezing is most active. This is not the fact however. Notwithstanding these objections many hold to this theory, among others the celebrated mountain-explorer, Whymper, alluded to on a previous page.

Some, too, have thought that the pressure or the friction of the ice on the bottom and on the sides of the valley causes heat, which melts the ice there, forming water all around the glacier so that it floats, as it were, down the valley. But at the sides of the glacier, where there is most water, which is caused by the direct and the reflected heat of the sun, and where in consequence the open spaces are widest, the glacier moves slowest; and besides, though there are streams of water underneath the glacier, they can exist only in channels, for the weight of the glacier would otherwise force all the water away from under it. Still, it is a fact that these Alpine glaciers move fastest in summer, when the ice is melting fastest, though there is not much difference on the whole between the day and night motion. It would seem, then, that water has something to do with this motion.

These theories did not explain how ice bends around curves, divides, reunites, contracts and spreads out. These peculiarities of ice-streams were the subject of many experiments by some scientific men, who came to the conclusion that ice is a "plastic" or "viscous" substance,—that is, a substance like clay, asphalt, liquorice or taffy-candy, which, though it may often seem hard and solid, can really be moulded into any shape by pressure, though it may be with extreme slowness. Hence the glacier, starting with the névé of the snow-field, is pushed down the valley by the outward pressure of the deep mass up there, and as it moves slowly down, the yielding nature of the ice enables it to accommodate itself to all the various windings and inequalities of its valley, letting it pass through gorges, and then, when free from confining walls, spreading out, as we know asphalt or the candy does. This "plastic" theory, as it is called, would seem admirably to meet all the requirements of ice-motion.

However, it has been objected* that, although ice seems plastic, it really is not so, but is rigid. The melting point of ice under ordinary conditions is 32° Fahrenheit (0° Centigrade); if pressure be applied, it will melt at a temperature several degrees below this, but the moment the pressure is removed the water formed will freeze to ice again. The pressure exerted on the névé in forcing it outward, produces this melting, which fills the vacant spaces between the particles of granular ice with water that instantly freezes, thus converting all into solid ice. When the ice in its motion down the valley meets with any obstacle at bottom or sides or middle, the pressure from behind causes melting in the parts in contact with the obstacle, which thus permits the ice to pass the obstacle ; but as soon as this is done and the pressure removed, the water freezes and the ice in consequence spreads back to its former place. Pressure is exerted in the same way at a gorge, or any narrowing in the channel ; at a broadening in the channel or at the end of the glacier, where the confinement (which is really pressure) is removed, the weight of the ice itself furnishes the pressure to make the glacier spread out, becoming thinner at the same time. The process of freezing again in this manner is called "regelation."

This "regelation theory" points out how the ice, while appearing to be plastic, or viscous, may really not be so. One of the proofs offered for this theory is the well known fact that two blocks of ice, even if their surfaces are melting, will, on being placed one on the other, or even closely side by side, freeze together.† Another proof given is, that if a heavy weight be hung by a piece of fine wire round a block of ice, the pressure thus caused below the wire will gradually melt the ice till the wire passes entirely through the block, the cut filling up again by the regelation of the water formed by the extra pressure.

Whichever theory is correct, or whether all contain truth, (which is the more probable), the fact that glaciers move in the ways indicated is undoubted.

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*By Lord Kelvin among others.

†This is the reason why sawdust is put between cakes of ice when packed away in the ice-house.

RATE OF GLACIER MOTION. It has been found that the rate at which glaciers move down their valleys, varies very materially. The Mer de Glace of western Switzerland moves daily in summer and fall from 20 to 27 inches in the centre, and from 13 to 19½ inches at the sides; a glacier in western Greenland is said to move from 48 to 65 feet per day. The Alpine glaciers on the whole move from 100 to 500 feet per year, while the great glaciers of Greenland and Alaska move, apparently, much faster. This last fact shows that difference in climate does not affect the movement of these masses of ice, though the Alpine glaciers move faster in summer than in winter.

It would seem that glaciers have their periods of advance and retreat, though upon the whole they have been retreating for very many years past. Some of those in Switzerland have been advancing for a number of years, others have long been retreating, while the great Muir glacier of Alaska retreated, it is said, over half a mile in four years preceding 1890; it seems to be a fact that those of Greenland are also growing smaller.

SIZE OF GLACIERS. Glaciers vary greatly in size, from the hanging glacier that just clings to a little valley far up in the mountains and stays there, to the great Humboldt Glacier in northern Greenland, which fronts the sea with a wall of ice 60 miles long and 300 feet high, or to the Muir Glacier in Alaska, which extends into the sea, and is said to be equally long and to be a thousand feet in height, 200 being out of water. In the Alps the largest is the Aletsch Glacier, which is ten miles long and 5000 feet broad, though of the two thousand glaciers that the Alps contain the average length is from three to five miles. These Alpine glaciers, some of them, are thought to be from 800 to 1,200 feet thick. In the Caucasus one glacier was observed to end in an almost perpendicular wall of ice 450 feet thick.

TOP OF THE GLACIER. MORAINES. The shape of the top of a glacier is that of a low dome with a rough outline, especially in its lower courses, for the tendency of ice, as is well known, is to "honey-comb" in melting. On the glacier this tendency is greatly increased by the boulders and the patches and bands of dirt that accumulate upon it. These prevent the sun's rays from reaching the ice below them, and so while all the rest melts away, these protected spots will stand out as stone-capped or earth-capped cones of ice often eight or ten feet high. At last the cover falls and the pyramid remains to roughen the surface.

Crevasses do not always close entirely, especially when formed in summer; for then the sun melts their edges rapidly, and the streams of water, which are always running in summer, plunge into them, (forming

what are called "moulins,"—mills), thus further enlarging them; they therefore cannot fully close, and when covered by snow-drifts during a storm, render glacier-travelling dangerous.

When an avalanche, great or small, falls into a glacier-valley it brings with it quantities of boulders, stones and rubbish from the mountain sides, just as the "house-roof" avalanches bring down eave-troughs, slating, etc., from the houses. These, together with others that fall without the aid of avalanches, collect on the edge of the glacier and form long lines, called "moraines," almost from end to end; and when side-glaciers join the main one,—for these are as common as tributaries are to a river,—only the moraine on the lower side of these continues on as a side moraine, the other will form a line at a greater or less distance out on the surface of the main glacier, a "medial" moraine, so that there may be several of these medial moraines, —according to the number of the side glaciers joining the main one. But long before the end of the glacier is reached these moraines lose their line shape, and the rubbish has been spread out all over the glacier by the water and the movements of the ice.

Thus the glaciers in their own way, and more literally, do what running water does,—carry their loads of mountain-waste down to the plain below, and drop them there. A few miles above the Great Glacier on the Stikine River is another glacier, which brings down so great a burden of waste that it goes among miners by the name of "Dirt Glacier."

WORK OF GLACIERS. But carrying burdens of rubbish on its back down to the plains below is not the only work of glaciers. We have seen that the heat, direct and reflected, of the sun often makes narrow openings between the glacier and the rocks,—just as, after a thaw, or a sunny day in winter, we have all seen little openings around a log that had been frozen fast in the ice of a pond, but that is now really afloat. Into these openings some of the moraine material falls, as it also does into the crevasses, reaching without doubt in this latter case, the bottom of the glacier. These stones and rubbish so caught between the ice and the bed rock at bottom and sides, together with others torn off by the glacier itself, are crushed with fearful force against the rock, cutting and polishing it, while they themselves are being ground down into the finest of

"rock flour." Thus when a glacier retreats, the bottom and sides are found to be all cut and grooved yet without any sharp projections—all have been ground away in the terrible mill.

Fig. 114. The Illecillewaet valley, Canadian Rocky Mts.; a glaciated valley snow-field visible; the stream, Illecillewaet River, comes from the glacier of the same name farther up valley, not seen here. C.P.R. crossing and recrossing river.

Edwards Bros., phot., Vancouver, B.C.

The rock at the bottom is often left in little low smooth hills and hollows,—"roches moutonnées," sheep-back rocks; but the valley itself is no longer a valley that a stream

would make it, in the shape of a **V**, but rather in the shape of a flaring **U**, with hollow-curved and regular sides, without precipices and their talus,—such a valley as the Illecillewaet valley, familiar to travellers by the Canadian Pacific Railway across the Rocky Mountains, a typical glaciated valley from which the glacier has only lately retired, but still lingering a huge mass of ice in the upper portion towards its snow-field.

This is the most important part of a glacier's work, and the valley is cut down and ground out far more rapidly than could be done by running water and weathering; for the wearing is not only constantly going on, but it is going on under enormous pressure, and therefore must be very energetic. But after all, how slow the process is! What a tedious ride a boulder has, which, being hurled upon the upper end of a glacier five miles long and moving two feet a day, reaches the place where it falls off after a journey of seventy years! But then neither the boulder nor Nature cares for time, however much men may think of it.

THE GLACIER FRONT.

When the glacier in its downward course reaches the point where the ice melts as fast as it advances, its progress ceases. The moraine matter drops and a great mound is built up all around the front, which with some glaciers is fully 400 feet high. In the years when the glacier retreats, this matter is spread out over the surface of the ground as a barren mass; but in years of advance the glacier overrides it or pushes it farther ahead. Thus the advance or retreat of a glacier can be readily traced by this moraine matter. And it is the presence of this matter far out in the plains of France and Switzerland, now cultivated and thickly peopled, that shows where the glaciers once extended to; it shows also that the climate now is warmer than it was when the ice could go so far from its birth-place before disappearing. Immense blocks of stone, too, perched high up on the sides of the lower valleys, but belonging to rocks of a kind found only many miles farther back in the mountains, tell the story of the vastly greater depth of the glaciers in days gone by.

When we consider how long it takes the ice to travel from the gathering ground to the lower end, and that all this time it is wasting beneath the rays of the sun, the warm winds, the rain, and the friction on sides and bottom, it is not surprising to find the lower end of the glacier much thinner than the upper end must be. As in the case of

the boulder, a mass of ice starting at the upper end of a glacier five miles long and moving two feet a day, will be thus exposed for seventy years. In summer, measurements on some glaciers have shown a melting away on top,—called "ablation,"—of nearly four inches a day. But this cannot take place in winter, and then the glacier must grow thicker and make up to some extent for the melting. But yet in most glaciers the ice thins out till its end is usually a somewhat steep, rounded hill of ice, full of great chasms, as in the Asulkan Glacier, (Fig. 115), and sometimes showing a series of gigantic steps or pyramids of ice, with a rough, irregular archway where the stream issues forth from beneath.

The water that thus comes from under the ice is never

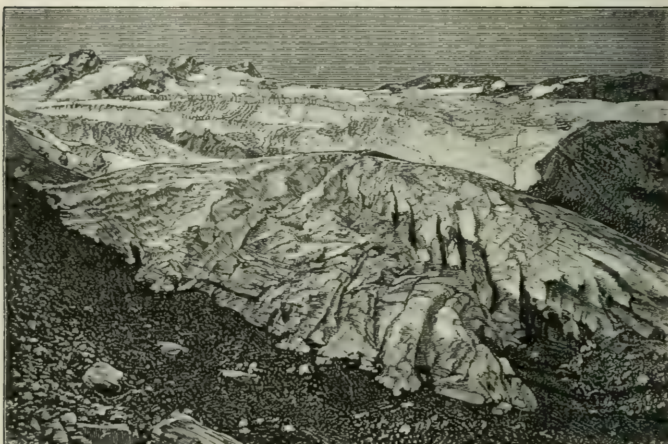

Fig. 115. The great Asulkan Glacier, Selkirk Range, Canadian Rocky Mountains.
Notman & Sons, phot., Montreal.

clear; sometimes it is only "of a peacock blue or green" color, caused by the presence of the "glacier-flour," which, however, soon disappears; but usually it is heavily laden with mud, the result of the grinding on bottom and sides. How far up the glacier bed streams begin, is not known; huge crevasses, very dangerous to explorers, are met with in the névé, but there can hardly be water so far up; so it is thought they begin where surface streams first enter crevasses, unless, indeed, the friction of the ice on the bottom develops heat enough to melt the ice and keep it liquid,—which is not known. It is from beneath the great

Mer de Glace of Chamouni that the Rhone gets its water and the sediment with which it is so rapidly filling up Lake Geneva.

CANADIAN GLACIERS. The glaciers of the Swiss Alps,—a little bunch of mountains in comparison with the vast mountain region of the Canadian west, and in the heart of Europe,—have naturally been more thoroughly explored and studied than the glaciers

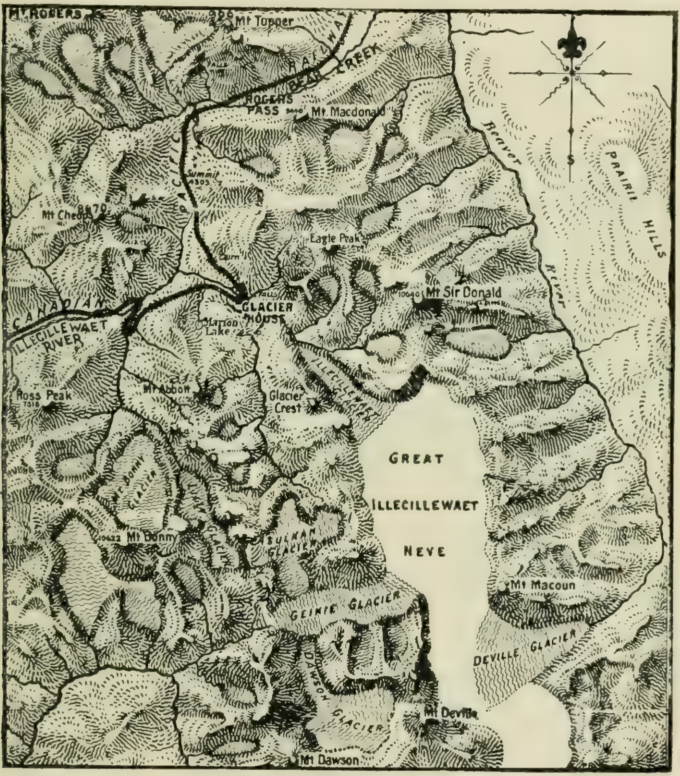

Fig. 116. Map of the Great Illecillewaet Névé with connected and other glaciers, mountains, etc., in vicinity; streams flowing from glaciers; Illecillewaet River running from Illecillewaet Glacier past Glacier House. Glaciers wavy-lined.

Courtesy of C.P.R. Company.

of any other country. Only of late years have those of north-western America received any attention, or indeed have they been known, except in a vague way, to exist at all. The explorations of the Geological Survey

of Canada, and the constructing of the railway across the mountains, show that glaciers are found everywhere throughout this mountain region, though none of them, so far as is known, except in northern British Columbia and in Alaska, come down to the foot of the mountains on which they are formed. Even yet those that are best known have not been scientifically studied.

Along the line of the Canadian Pacific Railway glaciers are seen on the summits soon after the Rocky Mountains are entered from the east, and from the highest of these, long icy arms stretch far down into the valleys which the streams and the ice have formed. Some of the snow-fields are very large; that of the Illecillewaet is said to be forty square miles in extent. It is near Glacier Station on the railway, not far to the west of the "Great Divide," between the eastern and the western slope of this mountain region, 5298 feet above sea-level, and some of its peaks rise fully a mile above this height.

It is a rough little plateau, covered, it might be said, with a great névé-river from which long branches flow into the numerous valleys that run down the sides in every direction. The largest of these branches is the Illecillewaet or Great Glacier. It comes down its valley farther than the others, but has evidently extended much lower than at present, for the moraine material that is spread over the valley, and the worn and evened and concaved state of the rocky sides, show the work of ice. All the other glaciers of this region are likewise retreating.

As everywhere else, a stream, the Illecillewaet, issues here from beneath the glacier; the water is the light greenish blue glacier water, which, however, soon loses its color. The main part ends in an arch of ice, as does also that of the Great Asulkan Glacier, the next largest arm of the plateau-glacier (Fig. 115). Great crevasses cleave the front of both glaciers at the sides, where they spread out, and above the arch as well.

The glaciers of the Stikine come down far lower in the valley than do the others just mentioned. But little is known of them accurately beyond where they end on the flat valley-bottom of the river. The Great Glacier is only about fourteen miles from the mouth of the river, while the Dirt Glacier is ten miles farther up the valley.

CONTINENTAL GLACIERS. As has been said elsewhere, Greenland is almost wholly buried beneath an ice-sheet, only the southern part and a narrow strip along the western coast are free. How thick the ice is cannot be determined, for there is no means of ascertaining the height of the underlying land ; only, near the eastern coast in a few places what are called "nunataks," evidently the peaks of buried mountains, stand out some thirty feet above the ice. The shape of the ice cap is that of a very low dome. It has been crossed only three or four times, for the journey is perilous in its length and desolation.

The Antarctic continent is apparently also covered by an ice-cap ; but we know very little of a definite character about this region. Its northern projections,—if they are projections and not islands,—are not thus buried but contain great glaciers in their valleys (Fig. 117). These for the most part extend to the sea.

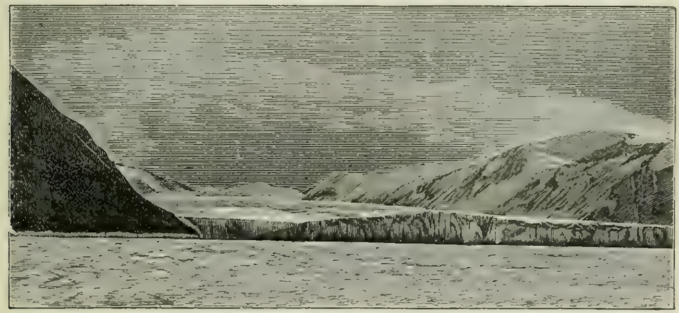

Fig. 117. A glacier entering the sea ; Antarctic continent. Borchgrevink.

ICEBERGS. It is the continental glaciers and the great glaciers of arctic or subarctic regions that supply the icebergs,—great "ice-mountains" that often bear away loads of waste to deposit it far out to sea. The great Muir Glacier of Alaska pushes out into the sea until the ice extends fully a thousand feet below the surface before it breaks. The force of the waves, together with the buoyancy of the ice itself, causes immense masses to break off and float away as icebergs, their bulk under water being about ten times as great as the bulk above. Borchgrevink, who went on an exploring expedition to the Antarctic in 1899-1900, relates that he went ashore about a mile away from where a great glacier entered the sea. Suddenly he was startled by a great roar, and looking towards the glacier saw an immense mass of ice breaking

off from its front. In a few seconds a huge wave, twenty feet or more high, came rolling on shore where he was, and it was only by desperately clinging to the rocks in what chanced to be a sheltered place, that his life was saved.

The icebergs from Greenland, Alaska, and elsewhere in the north, are all of an irregular rough character, while those of the Antarctic are built up of almost horizontal masses like great tables (Fig. 118). The explorer just mentioned accounts for this by the different ways in which they have been formed. Those in the north have in the

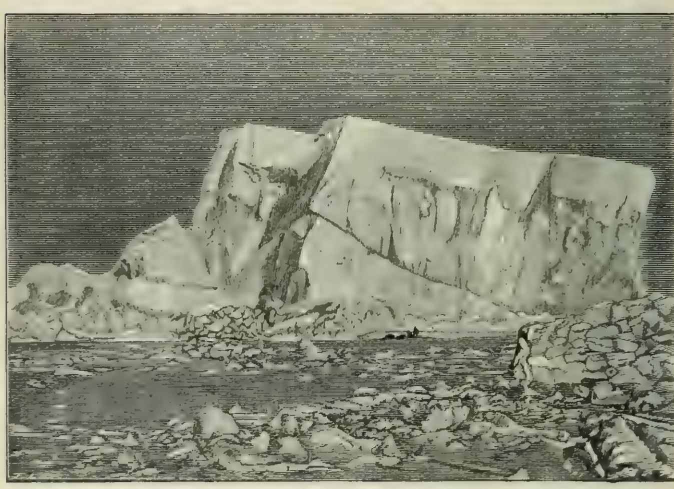

Fig. 118. An Antarctic Glacier. Borchgrevink.

main been formed in valleys, and the pressure to which they have been subjected has altered the original stratified form of the ice, and when they break off they upset; while the icebergs from the Antarctic continent have been formed on very low flat ground that shelves off very gradually beneath the water; and so they are pushed out far to sea in a horizontal position till they break off by their own buoyancy in much longer and broader masses than at the north, and thus sail away keeping their original horizontal position.

The glaciers of the Arctic regions do not have upon their surface the great quantities of waste that those in other regions have; still, icebergs are often seen carrying rocks on their surface or embedded in their sides. These are dropped as the ice melts. Many believe that the Banks of Newfoundland, that great shallow where untold myriads of fish feed, are in part caused by the quantities of ice-borne waste deposited there, for there the icebergs meet the warmer oceanic currents from the south and rapidly melt away.

But there is other ice than that of the glaciers, which carries off to sea great quantities of material. "In the Arctic sounds and bays the littoral waters freeze along the shores and form a cake of ice which, upborne by the tide and adhering to the land, is thickened by successive additions below, as well as by snow above, until it forms a shelf of ice 120 to 130 feet broad and 20 to 30 feet high. This shelf, known as the ice-foot, serves as a platform on which the abundant débris, loosened by the severe frosts of an Arctic winter, gathers at the foot of the cliffs. By means of the ice-foot an enormous quantity of earth and stones is every year borne away from the shore on the disrupted ice and strewn over the floor of the sounds, bays and channels." (Geikie.)

ANCIENT GLACIERS. Was there ice before the great Ice Age of Pleistocene times? Many geologists believe there was; some, indeed, think that traces of ice-action can be found away back in Silurian times, when, as is usually held, the earth was warm, even hot. It seems quite certain that there was ice in Carboniferous times at least, and from then downwards; for great blocks of stone, embedded in strata of a different kind, are often met with, and these, it is thought, could be transported only by ice; and again, beds of material are not uncommon that "in no way differ in appearance from modern ice-deposits," and some of them contain striated stones.

Thus the great work of glacier ice in cutting down high ground is to carry loads of waste to the plains below, to scoop out and grind down valleys, to fill the streams with sediment to be carried to the sea, and to form icebergs whose loads of waste are distributed far and wide over the ocean floor. The importance of this work of icebergs is referred to on page 120.

CHAPTER V.

THE COAST.

It is on the coast of the sea, and, to a lesser extent, of the greater lakes, that the restless activity of water in wearing away the land is seen in its most attractive form. The lapping of the water on the beach so quiet as scarcely to move a pebble or raise the faintest film of sand to cloud its clearness, the drifting of the currents, the strange ebb and flow of the tides now reaching the base of the shore-cliffs and a few hours later far away from and below them, and the dash and roar of the breakers mingled with the loud rattle of the beach-stones, which may be heard far away—all have a charm that never fails to attract even those who are most accustomed to them. And then the almost endless variety of form that the shore is worn into,—headland and harbor, point and inlet, cliff and low curving cove, beaches sand-strewn or of shelving rock and shingle,—adds still another charm that nothing inland, not even mountains or waterfalls, can equal. Indeed, the water here seems almost a living thing, and its ceaseless change of form was not inaptly represented among the ancient Greeks by the character of the sea-god, Proteus.

COAST FEATURES. The general shape of the great land-masses of the earth is due to widely-extended earth-movements, to upheaval or subsidence; the leading minor features, such as deep bays, long narrow inlets and projecting masses of land, while the result of upheaval or subsidence also, belong to land that, previous to these movements, had been weathered or eroded; but the more minute features, those that impart so much of the beautiful or striking to a coast, are the work of the waves. Yet not precisely of the waves alone, for the land surface, as in the case of the leading minor features, has been prepared for their work by the long and effective labour of the other agents of change,—weathering, running water, etc. The surface of the land has been worn into an endless variety of form,—hill and hollow, rounded elevation and flat plain, bold hard rock standing out here and deep alluvial deposits extending there, while rivers have cut deep grooves from far away inland down into the sea itself.

This unevenness of surface always makes unevenness of shore; for the waves cannot wear away a rocky cliff as fast

as they can a low-lying bank; nor can they wear away rock as fast as they can sand, or clay, or silt. The lofty shore will be left behind as a promontory, and the hill as a "point," or "head," or "cape," while the hollow will be worn back into a cove, and the alluvial plain into a broad sweeping bay. Inequality of surface and inequality of material will certainly be found out by the waves, and they will make it known by the inequality of their own work.

The rocks, too, on which the waves act, are not all of the same degree of hardness, or do not yield with the same degree of readiness to the influences of the atmosphere or of water. This fact, we know, has given us the "knife-edges" and the "sheer cliffs" that bound the deep and narrow valleys among the Rocky Mountains. Here, too, as among the mountains, the strata may lie horizontally, or they may be tilted or contorted to any degree; they may consist of massive granite, of column-forming or "flaky" trap, of table-like limestone, of coarse-grained sandstone, of splintering slate, or of rock of any other characteristic, all yielding to the waves in different degrees and in different ways, giving to the shore as endless a variety as is seen among mountains.

Then, not all parts of a coast are equally exposed to the action of the waves; some are sheltered from the most violent storms, while others stand out against their wildest fury; and as the destructive power of the waves depends on the force with which they act, the exposed shores must wear away faster than the sheltered ones. Neither are currents, tidal or other, the same everywhere; in some places their sweep along the shore or the beach is strong enough to move not only silt and sand but even cobble-stones, while in other places there seems to be no current at all.

It appears, therefore, impossible that the coast should anywhere, except for a short distance, be to any degree regular.

It must not be forgotten, either, that in northern Europe and in northern America much of the irregularity of the coast is the work of the Ice Age and its great glaciers. The great tongues of ice that filled the old depressions and the river valleys and entered the sea from them, dug them

deeper than the sea-level and wider and farther back; and so when the ice was gone, the salt water took the place of the tongues great and small, and the valleys and the lower reaches of the rivers remain till now as long deep "inlets" of the sea with peninsulas or promontories between them.

Finally, to add to the causes of its unevenness, the coast is in many places not at rest; it is either rising or sinking; so that the waves, whose tendency is to make the coast even, have to see the places on which they have made some impression, sink below their action or rise out of their reach.

FORCE OF WAVES. In the streams the motion of the water has little eroding effect, as we have seen; the water carries along the sediment, and it is the rubbing of this against the bottom and banks that causes the destruction, not the force with which the water itself moves. But on the sea-shore it is largely, though certainly not chiefly, the force with which the water moves,—that is, the force with which the waves are driven against the shore,—that does the work.

Where the shore is exposed to the full sweep of the wind, the gales of winter hurl waves upon it that strike with a force of three tons or more to a square foot. In the Shetland Islands "blocks of rock up to nine and a half tons in weight had been washed together at a height of nearly sixty feet above the sea," and "blocks weighing from six to thirteen and a half tons had been actually quarried out of the original bed at a height of from seventy to seventy-five feet." In Shetland also breakers have been known to dash 196 feet high with sufficient force to overthrow a wall and break in doors." (Geikie.) No work of man, built to check the power of the waves, has ever effectually done so, as the wrecks of huge piers and sea-walls along the coast of Great Britain, where if anywhere such works would be solidly built, abundantly testify. Such is the power at work on the edges of the land.

HOW WAVES WORK. Waves do their work in more ways than one. Rocks are full of joints, cracks, caves, or openings of some kind, and when a wave rushes against them with the great force that it sometimes has, the air in these cavities is suddenly and violently condensed,

and forced even into the pores of the rock, bursting off fragments large and small, just as a charge of blasting-powder or of dynamite would do; and then when the wave has spent its force and it drops away from the cliff, the sudden release from pressure causes the confined and compressed air to expand, and this too tears off fragments. Or, if the air can readily escape from the cracks, the wave drives long tongues of water far into them, which, like the hardest of wedges,—for water so confined is more unyielding than iron,—splits off huge fragments that fall and encumber the beach below.

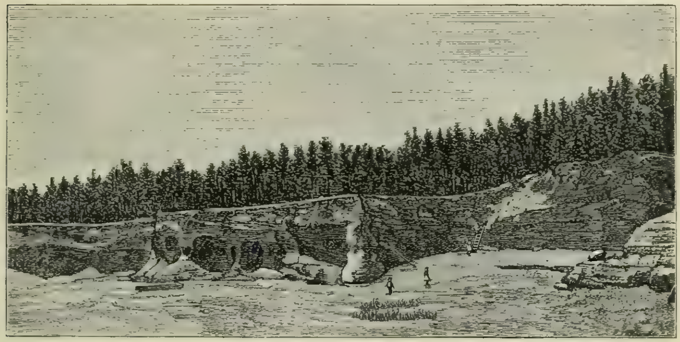

Fig. 118. Low shore-cliff of coarse red sandstone, hollowed into a cove, and dug into shallow caves by waves. Starr's Point, western side of Minas Basin, Nova Scotia.

But this bursting and rending force of the waves, important and striking as it may be, is after all not the chief means of shore-erosion that the sea possesses. Any-one who has stood on the shore and watched the waves rushing up the beach, has heard amidst the dash and roar of the water, the sharp rattle of the pebbles that the force of the waves drives against the rock and often sends bounding back from the seething water into the air; and as the water dropped back he has seen it weighted down, as it were, with sand. No rock, however hard or compact, can withstand this combined cannonade and sand-blast of the sea. Erosion at such a time is very active, and shows itself in the hollows and caverns cut low down

in the rocks, in the smoothened surface of the rocks, and in the utter absence of any sharp or angular projections from them.

We have seen, also, that sea water as well as fresh water, contains several chemical elements, — chlorine, sodium, magnesium and others; these act on the rocks of the shore and greatly help the waves in their work of erosion. Where the shore is of igneous rock, especially trap, as are the shores of the Bay of Fundy in Nova Scotia, this chemical help is highly important. For not only is trap full of joints (Figs. 121, 123), but it is traversed in all directions by numerous veins containing minerals readily acted upon by the salt water. And so the face of the cliffs often has a strangely gashed look, the gashes, sometimes only a few inches wide, running deep into the cliff throughout its whole height. It is in such places that the waves do their bursting work.

At times a broad vein comes out on the top and extends far back from the cliff. Here weathering forms a channel for a stream, which, pouring over the cliff, cuts, with the help of the waves, so deep and wide an inlet that a breakwater is often built part way across the entrance so as to form a miniature harbor, the only kind on this harborless, cliff-bound coast. Or again these veins may be worn away by the waves so far back into the cliff, and so far upward that, unless the shore is too high, openings will be made at the top, so that when a wave dashes into the mouth of the cavern, there will be a strong uprush of air out of these holes, or even of salt water and pebbles; "blow holes" is the common name of these openings; or, as with underground water-courses, the whole top may fall in, and thus a little inlet will be formed, or rather revealed.

To illustrate the action of waves on a shore, such as is found the world over, we will take some particular instances.

SHORE EROSION. Fig. 118 shows the central portion, and Figs. 119 and 120 the southern and the northern wing respectively, of a low shore-cliff on the western side of Minas Basin. It is the end of a narrow tongue of land, less than a quarter of a mile wide, lying between

the mouths of two of the short tidal streams that cut this valley (see pages 30, 31) into several rounded ridges. The rock is coarse loosely-packed red sandstone, a kind that both the dash of waves and weathering will wear away rapidly. Here (Fig. 118) the waves have set more strongly against one portion than against the others, and so they have hollowed out a little cove, although the cliff is somewhat higher than elsewhere. On the left the waves with their "sand-blast" have dug out many little caves separated by walls, some of which are pierced, as the rock in Fig. 120 is seen to be. Except in sheltered spots few boulders are seen on the beach, for although masses of rock fall from the cliff, their soft material cannot long stand the knocking about on the beach, or else the ice, which here piles upon the

Fig. 119. End of southern (left) wing of shore-cliff shown in Fig. 118. On right remnant of stack formerly the end of shore-cliff, but cut off by action of waves. Distance between stack and cliff about 500 feet.

beach under an eastern gale, carries them off during some high tide when, after the wind has shifted, it floats away again. The rocky hillocks, seen at the foot of the cliff, were once the divisions between caves now gone, and their smoothened rounded appearance shows the scouring work of the sand-laden waves.

Only fifteen or twenty rods to the left of the part of the shore seen in Fig. 118, is the southern corner or wing of the cliff. Here the waves have broken through the projecting wing and cut off a mass from its connection with the shore. The erosion has been very rapid, and while the severed block has been wearing down, the shore has been

retreating; and what is in prospect for both stack and shore is seen in the vista beyond,—a wide mud flat.

Fig. 120 shows the northern wing of the cliff. It projects several hundred feet beyond the main body of the cliff, because the sandstone is finer and firmer than elsewhere; but as with the other wing, its situation exposes it to attack by the waves on both sides, and a hole has been broken through it which will ere long enlarge so much that the "natural bridge" thus formed will fall in, leaving the end standing alone as a stack,—to share the fate soon to overtake the one on the other wing. (Cf. Fig. 34, page 41.)

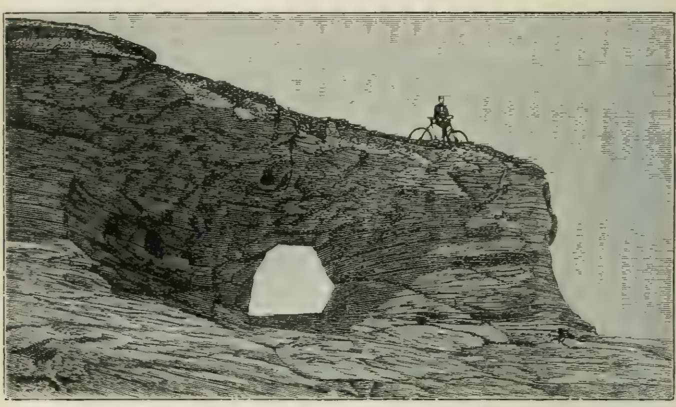

Fig. 120. Northern (right) wing of shore-cliff shown in Fig. 118; rock pierced by action of waves.

Very different from this shore is the shore of the Bay of Fundy some twelve miles distant. Here for a stretch of over a hundred miles the shore is of basaltic trap, one of the hardest of rocks (page 32). In Fig. 121, and still more plainly in Fig. 122, these rocks are seen to be bedded; indeed this long ridge seems to have been built up by different flows of lava followed by outbursts of volcanic ashes, which have formed alternate beds with the lava. The beds of ashes, or tufa, are now rock, but far softer than the basaltic trap, and crumble very rapidly. The shore in most places rises in perpendicular cliffs (Figs. 48 and 122), but at times sinks low, as in Fig. 121.

The range of tides is very great here; they rise and fall off fully forty, or even forty-five, feet in perpendicular height; and when heavy gales are blowing direct on this very exposed shore during a spring tide, the waves dash far beyond high water mark. In the stretch of shore shown in Fig. 121, the tides in quiet weather never reach the foot of the highest terrace; but when a winter's storm is on, the waves pile driftwood on its top and far beyond its edge. And so the waves have swept this upper terrace (which is of the tufaceous trap, weathered,) far back from off the bed of hard basaltic trap beneath it. Below this last bed the layer of the soft rock is thin, as such are seen to be in the

Fig. 121. Low shore of basaltic trap (ancient lava) falling off in terrace form. Top of middle terrace is in all respects like a modern lava bed, harsh to the touch and full of shrinkage cracks that give the surface a plated look. The cracks, or joints, extend deep into the rock as seen in the beach-worn bed in foreground; the grooves all follow these cracks. Bay of Fundy.

bold cliff partly shown in Fig. 122, and, as it is on a level with the beach, the waves have little chance to undercut the hard bed (except as seen on the right) and so it is only by chemical erosion and wave erosion, not by breaking, that the shore is worn away. But elsewhere along the shore, where these soft beds are thicker and lie higher up, boulders of great size break off and cumber the terrace below, though some find their way far down the beach near to low-water mark, so fearful at times is the force of the winter waves here.

Where as seen in Figs. 48 and 122 the soft layers are thin and high up from the beach, within reach only of the heaviest waves, frost and other forms of weathering do more than the waves;—great quantities of the rock split off along the joints and fall to the beach (Fig. 48); this mass the waves and ice soon remove, and the cliff is kept perpendicular, as with the Scarboro Heights.

OTHER SHORES. As it is with this practically jointless sandstone and the jointed and bedded trap, so it is with all kinds of rock; the waves by their very force, by the pebbles and sand with which they are laden, or by their chemical action, will search out the weakness of the rocks and destroy them. They may not all wear away in vertical cliffs, for the joints along which, as we have seen, the rocks split or erode, may not run vertically or horizontally; the beds may be tilted in different degrees and in different directions, and so instead of an almost even face, the shore-cliffs will have a broken and rugged face. Sometimes the beds slope down from the shore and pass beneath the water; such a shore, if of hard rock without joints, would seem to bid defiance to the waves. The work of erosion here is very slow indeed. But such are seldom found; even granite has its seams and cracks, and in these the work of destruction will go on, as the shores of the Maritime Provinces show full well.

It is the same on the shores of lakes, though here, except in the Great Lakes where they are as large as those of the sea, the waves are smaller and cannot work so fast. Yet frequenters of the islands and shores of Georgian Bay and of the Muskoka lakes, will drop their lines for black bass where, a few feet under water, they can see a probable lurking place among great boulders piled together there; the sheer blank face of the cliff overhead, or its rugged and broken shoulders, will show where the boulders came from.

Where, as on reaches of the Bay of Quinté, or along the southern borders of Georgian Bay, horizontally bedded limestones form the shores, the cliffs rise vertically out of the water. It is a repetition of the Niagara escarpment, only there is no talus,—no sloping pile of waste at the foot

of the cliff, for the waves remove all that weathering sends down to them, as well as all that they tear away themselves. It is very instructive to sail quietly along close up to these wall-like shores,—for there is no tide here to prevent or interrupt it, — and look at them. Sometimes for rods together, close down to and a little under the water, the rocks look as if a huge set of carpenter's match-planes had been pushed along the cliff, leaving tongues and grooves behind them. For the lapping wavelets have found the horizontal joints and bedding-lines, and dissolved or worn their way in between the intervening hard layers, which stand out sharp-edged tongues between the grooves. The water, as it drops out of the grooves, has a milky streak or two in it,—the limestone that has dissolved; and the fingers, if put in the grooves, will bring away a little pasty mass,—limestone, too,—that the water has softened to mud, ready to be washed away.

Sometimes a concave spot is met with, and around it the limestone is shelling off; the waves have found the joints behind and are bursting pieces away; sometimes a hole, generally rectangular, is seen with the water running in or pouring out as the wavelets strike or draw back from the rocks. Here, before long, during an on-shore storm, big boulders will be rent away. But by whatever means the shore is here worn back, the horizontal bedding joints, and those at right angles to them, keep the cliff perpendicular (Fig. 41).

SHORES WITHOUT ROCKS. Where the shores along the sea or along a lake are of softer material than is called rock, — of clay, till, sand, drift, — the waves have easy work, and they work rapidly. Along our Great Lakes the loss is a matter of serious importance; Scarboro Heights retreat about four and a half feet a year, though probably the loss is not more than one foot around the whole lake*; along Lake Erie in Kent county, the road that skirts the banks, has to be moved back every three or four years. The eastern shores of England are of clay and are exposed to frequent and heavy "north-easters"; so rapid is the waste that in some places fifteen feet a year is washed

*Prof. Coleman, Univ. of Toronto.

from the land into the North Sea. Ravenspurg, in Yorkshire, where the Duke of Hereford landed in 1400 to claim his estates and the crown, has long since been covered with water; the spot where it stood is now far out from the shore. Since the Norman Conquest this coast has lost over a mile in breadth.

On shores of this kind it is not so much the steady wash of the water that causes the destruction,—each wave, as it falls back from the shore, carrying with it its little load of mud,—but it is the undermining force of the waves as they drive against the shore. They force the water into every crack or crevice, and then the cliff, from top to bottom, often acres at a time, slips away and pushes out across the beach, carrying with it fields and crops and villages, and people. Such disasters have always been occurring in historical times on the eastern coast of England. It is thus in a great measure that the cliffs at Scarboro Heights retreat, the jointed structure of the till keeping the cliffs perpendicular, and helping the waves by favouring the splitting work of frost and rain (Figs. 44, 45). The same undermining by the wash of the water, and the same slipping down of long stretches of the bank are seen along the Ottawa in Prescott county, where clay covers the country.

Even on low shores that are thought to be rising, the destructive work of waves is seen. During storms bars and sandbanks are literally swept away, islands have great gaps cut in them or, as is often the case with Sable Island off the coast of Nova Scotia, are cut through from side to side, while steep sandbanks high up the beach show how far the breakers have reached, and how much sand they have swept away. Easterly storms are a cause of dread along the low eastern coast of the United States from New York to Florida.

Perhaps in no other part of the world is the destructive force of waves shown on so grand a scale as in the north of Scotland and the islands beyond. Every kind of rock from hard granite and gneiss to soft sandstone, seems to yield with almost equal readiness to the force of the wild waves in this exposed region. Peninsulas are pierced and

their extremities become islands only to be reduced ere long to groups of fantastic columns of rock, or stacks, rising at times a thousand feet out of the surrounding water. The coast is lined with these skeletons of the past (Fig. 50).

BEACHES.

We call by the name of "beach" that sloping strip of land lying between the lowest level of an expanse of water and the point to which the water reaches when raised by the tides or forced by the storms. It is in reality the upper limit of the continental shelf, covered only at times by the water, and ending at the shore.

Here, on the beach, "the trampling waves" work their work by themselves; they have, as it were, their victim, the land, beneath their feet and will destroy it.

WHERE BEACHES ARE. Not everywhere around the coast of sea or lake is there a beach, even though there may be a great range of tide. On rocky coasts the shore may rise more or less steeply out of deep water, and here either the waves remove what they tear from the cliff, or, as some think, the shore is sinking, and so the waves cannot form a beach. Wherever the great glacier appeared on the coast, there the sloping rocks commonly dip down under the water with no beach around their margin. We see this all around our shores both of ocean and lake. But yet, even here, in the coves and bays and inlets beaches are always present; for the headlands and other projections behind which these lie, cause the currents that always sweep along the coasts, to eddy round into the hollows, where, slacking their speed, they leave behind part of their load of sand or pebbles in the quieter water. In these coves and bays, too, the shore is usually, though not always, low, for the material of which it is composed has weathered away at the top more rapidly than the waves have wasted it at the edges, and the sloping shore thus formed allows the waves to sweep up on the land and then to retire from it, a beach being the result.

Where the shore-rock is jointed, as already explained, and hard, a wide beach is apt to be formed; for the rock readily splits off along the vertical joints but is not readily worn away across the grain, so to speak: the shore-cliffs thus retreat faster than the beach wears down, till at last

a point seems to be reached in which the two are about equal—a "mature beach." Fig. 122 shows such a beach, extending from near low-water mark to the base of the perpendicular shore-cliff, a distance of fully 250 feet.

The soft limestone rock of our lake-shores yields too readily to water to form beaches; and so, though the cliffs keep perpendicular, as we see them in the Bay of Quinté, on Manitoulin, and on the southern shores of Lake Huron, no beaches of importance are met with at their base; our open-lake beaches are the wash from the drift-covered shores.

But the broadest beaches are found where in tidal waters the coast is rising, or where the broad deep curves produce the eddies that, as they become more and more quiet, drop their load of sand over wide areas: the low shore that both elevation and silting up thus give, allows the waves to sweep far up above the water's lowest level, and here are the broad sandy beaches, broad even at high-water, that are so marked a feature of the Atlantic coast from Cape Cod southward, and especially so in the great bend of the coast in which Long Island lies—bathing grounds of limitless extent. Such beaches, but naturally not so broad, are well known around the Great Lakes—at the low mouth of the Humber, for instance, on Toronto Island, and at other bathing resorts in the neighborhood of Toronto.

FORM OF A BEACH. The slope of beaches is very various. Along a high shore of hard rock where the beach is not yet fully formed, or "mature," the slope is apt to be steep; while along a low, rockless coast the sandy beach will pass beneath the water with a very gentle slope indeed. The mature beach, seen in Fig. 122, has an upward slope of about twelve degrees. The slope depends on the character of the bed-rock, on that of the shore, and on the age of the beach.

It is along a shore with a mature beach, such as that in Fig. 122, that the characteristics of beaches are best seen. At the low-water mark, the beach is almost flat, and the water outside seldom deepens as fast as the upper beach slopes downward. From low water the beach rises in a gentle curve, increasing in steepness as it nears the upper rim, just as does a river bank. Then as the shore, whether rocky or not, usually wears back in a succession of curves—indentations and points—the outer rim of the beach shows the same peculiarity, though off the ends of the points the beach is sure to be rocky if the shore is

such. Besides, the beach between the points is concave, a wide shallow groove, though at the base of the shore this feature is to a great extent lost. The study of the action of water along a coast is most instructive.

WAVES ON THE BEACH. Waves rush at a shore and hurl sand and stones against it; upon a beach they fall headlong down with all their weight and all the force with which the wind drives them, and then rushing up the slope, they push sand and pebbles and cobble-stones before them, at the same time crushing and grinding them against the bed rock, and against one another, and in their wildest energy they roll hither and thither masses of rock, tons in weight, that they have torn from the cliff. And then to complete their work, when their shoreward force is spent, they turn and rush down the slope, dragging back with them the fragments they have torn from the cliffs, and the stones that a moment before they had driven in front of them.

But it is not always rush and turmoil on the beach; nor is there always the roar of waves and the grind of shingle. In the quiet days of summer the incoming or the outgoing tide makes scarcely more than a little curl of water, which merely chatters with the pebbles, as it slips in among them; or at most it is only a little swell of water that, as it nears the beach from the open, rises and curves over into a greenish arch a foot or two high, capped towards one end with white, and falling in foam on stones or sand, scarcely doing more than calling forth a little cry of pleased fear from timid bathers. The erosion on the beach is then no more than in the bed of a summer brook.

BEACH—MATERIAL AND ARRANGEMENT. "As a rule the coarse materials are thrown up about the upper limit of the beach . . . Below the limit of coarse shingle on the beach lies the zone of fine gravel, and then that of sand, the sediment, though liable to irregular distribution, yet tending to arrange itself according to coarseness and specific gravity, the rougher and heavier detritus lying at the upper, the finer and lighter at the lower edge of the shore." (Geikie.)

Fig. 122 represents a portion of a beach, about 250 feet wide, on the Bay of Fundy. It will be seen that here the arrangement is exactly the opposite of that stated in the quotation—the coarser material is on the lowest edge of the beach, the finest sand at the upper edge, at the foot of the shore-cliff. But the slope of a beach and the presence or absence of bed-rock near the surface, the size and force of the waves, and many other considerations, have to do with the arrangement of the material.

The beach in Fig. 122 is somewhat steep, and the boulders are resting on the bed-rock. When the breaker

falls over upon the lower edge, it jostles the stones about, but the lighter pebbles and the sand are swept forward by the rush of water up the beach, the lighter they are the more they are at the mercy of the wave. At the foot of the cliff, in the slight pause ere the wave turns to run down again, the sand and pebbles fall; the sand packs close on the bottom and the backwash cannot catch hold of it, as it were, to carry it back; but it seizes the pebbles and carries them a little way; the larger stones, on the other hand, catch the full force of the wave rushing down the beach, and are dragged down till a new wave is met.

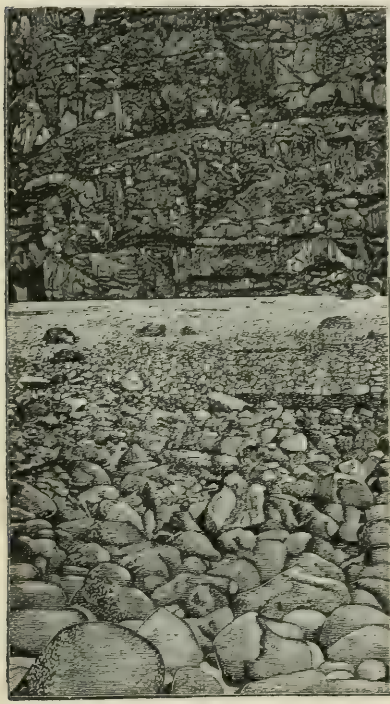

Fig. 122. A typical beach on Bay of Fundy, Nova Scotia; boulders in foreground gradually becoming smaller toward shore; upper edge, sand; boulders rest on bed-rock. Face of cliff shows thick beds of basaltic trap, with beds of volcanic ash, or tufa (amygdaloid trap) between.

The origin of the boulders, pebbles, and sand is seen in Fig. 48—the masses of rock that have been torn from the cliff; so that on such beaches as this one, the work of the waves, after tearing off or helping to tear off fragments from the cliff, is to drag them down as far as they can, and there jostling them about and against each other, slowly to carry them up the beach again as they get smaller, till as pebbles and then as sand they occupy once more the upper edge of the beach. Here the sand is ground down into fine mud, to be swept away by the waves and deposited in deep water to be at last rock again.

While the sand, whether at the upper or lower edge of a beach, is generally spread out evenly, the pebbles are very commonly in ridges. The one highest up of all, often, indeed, beyond the bounds of the beach, is the result of some unusually high tide, or some unusually severe storm. When the tides are "nipping off,"—gradually rising less high,—each tide, if there is any surf on, leaves its own ridge of pebbles, to be destroyed by the waves of some storm or by the returning high tides.

In these ridges the waves often show very curious sorting power. At one end the pebbles are coarse but gradually grow smaller and smaller—like small round eggs, then like marbles, peas, shot—till at the other end there is only sand; or there are alternate ridges of pebbles and gravel, so regular in size that they seem to have been purposely sorted through a carefully meshed screen. Sometimes the ridges farthest up the beach present a long, sloping front to the advancing waves, packed so hard and close that the foot can make little impression on it; while the slope facing shoreward is steep, at times almost perpendicular, the pebbles being so loosely and yet so carefully piled that the foot will sink to the ankle in them,—as if the last expiring effort of the waves had spent itself in pushing the pebbles thus far and could do no more, sinking out of sight in the loose heap they themselves had built.

The tossing and rolling about of stones on the beach tends to make them round; with granite, gneissic and basaltic rocks, and others that are not regularly jointed, this is especially the case. On the beach at Oakville the stones are all thin ovals, shaped like the hand, and wear down into fine flat "skipping-stones"; for they all come from thin beds of limestone that are here mingled with thicker beds of muddy shale.

SHELLS ON BEACH. But the beach-walker sees other material besides those mentioned. He takes up a handful of sand, and finds multitudes of little bits of shell in it—blue, white, pink—and a lens will show more than the naked eye sees; among the pebbles he finds large fragments or whole shells of univalve shell-fish, or half-shells of bivalves,* often pierced on the shoulder with a little hole of the diameter of a darning-needle, through which the borer, or "tongue," of a kind of periwinkle has pierced into the soft flesh beneath, whose

* "Bivalves," such as the oyster, clam, and mussel, whose shell consists of two valves, or sides, hinged along one edge toward the back; "univalves," shells of one valve, terminating at one end in a spiral or whorl, sometimes quite sharp, and at the other in a mouth or opening, turned more or less to one side, such as the periwinkle.

juices he extracts, to the death of the victim; or the crows have tugged and wrenched off mussels from their anchoring place in crevices in the rocks at low-water mark, and carried them high in air over the rocks of the upper beach, and there letting them drop, as shore-dwellers declare, fly down to feast upon the sweet contents of the now broken shells; or rather, the crows carry their tough-shelled prey up out of the way of the incoming tide, where, at leisure and free from danger, they may pound and break open with their powerful neck and beak the valves between which lies their much prized food. Certainly, not only the rocks of the upper beach but the high shore itself is strewn with these empty shells. The lobster, too, does his part in this shell-making; for, as he crawls about in the shallow water with his slender feelers alert, and his keen bead-like eyes standing out on the top of their restless stems, he seizes on some unlucky mussel with his sharp-toothed left claw, and, holding it fast, crushes its shell with his far larger and blunt-toothed right claw—for lobsters are right and left handed. And the waves wash all within their reach to the upper beach, where they are ground to atoms in the whirling mill there.

It must be borne in mind that, whatever the arrangement of beach material may be, whether that of the Bay of Fundy beach or the converse, storms are apt to confuse all, and mingle sand and stones and pebbles together in one mass. And should a beach thus mingled sink, and after long ages become rock and rise again, it will be a "conglomerate;" but the stretches of sand which now form smooth, gently sloping bathing places or wide extended shallows, will be found turned to great beds of sandstone:—our day will bequeath to ages and periods to come what past ages and periods have bequeathed to us.*

A BEACH SAW. Where the shore is low and the rocks slope down the beach to the water, they are often destroyed in the manner shown in Fig. 123. A vein in the rock (see page 228) has been found, whose mineral has been broken out, and the pebbles and shingle surging back and forth, like the teeth of a great saw, as the waves dashed up along the groove and then rushed back, have done their work. The mass has been cut in two, and now their further work is to widen the passage by cutting sideways: the smooth, bare sides show what is in progress, although bunches of seaweed nestle in the crevices and little hollows above the reach of the surging pebbles; but the rock on

* Within a few yards of the spot pictured in Fig. 35 is a thick bed of gravel, the grains of which are of a markedly uniform size, about as large as peas, exactly like the ridges on modern beaches referred to above.

the right foreground tells the story of what has been and what is coming. Sometimes where the shingle is not very abundant, the cut is narrow, though deep; here a chance wave often sweeps the cut free from shingle, when a beautifully smooth and curved bottom is seen, but always with the vein or crack running along it.

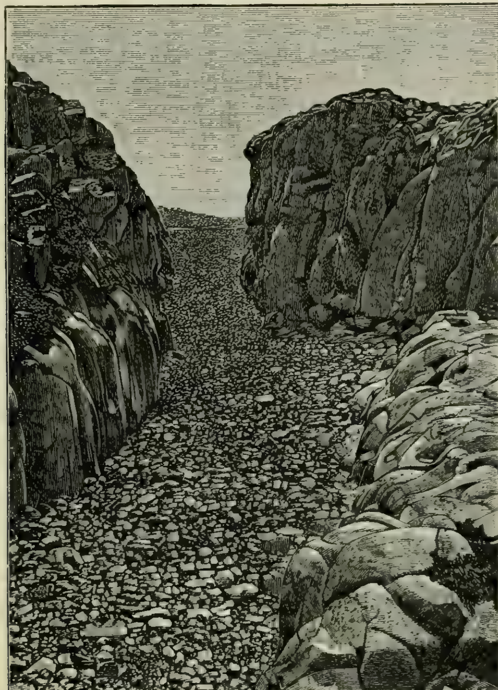

Fig. 123. A "Beach Saw"; passage cut by beach shingle along a vein through a mass of basaltic trap; rock in right foreground much worn down and smooth, showing shrinkage cracks also; slope of shingle about 20°. Bay of Fundy.

Should the shelving rocks here have spread for any extent over the beach, they will be found everywhere cut by such passages. On the lower beach these remnants, which have been the longest exposed to the work of the shingle and waves, are not, as a rule, very thick. And here these destroyers show another mode of attack. On the level of

the beach they cut low passages or hollows beneath the rocks, shearing, as it were, the top off, forming thus fine hiding places for the lobster, whence, however, the prowling boy with his long-handled gaff drags him forth, vainly resisting and direfully threatening with his powerful claws; and on the tops and sides of the rocks beds of protecting seaweed cling, which, too, may shelter the same crustacean in crevices and hollows that they mass over. Great boulders, hundreds of tons in weight, are thus cut off from the bed-rock, and, settling down on the shingle, are again attacked in the same way, till they, too, become shingle and sand and mud.

Curiously, too, shoreward behind these great boulders, where the incoming tide and waves eddy round from both sides, little mounds, rounded or knife-edged on top, are formed from what the waves bring up and drop there in the eddy,—pebbles at the bottom, sand and shell fragments at top. It is a sort of miniature of what goes on at the head of the beach.

SHORE-DRIFT. The tendency of the waves is always to move dead on shore (see "Waves," pages 269, 270); but the winds and currents will not always permit this, so that they drift along the edge of the beach or shore, approaching it diagonally, one end striking and breaking with foam before the other. In this way the beach material, even the large stones, may be swept along the beach instead of right up it, so that it is never certain that the beach matter belongs to the immediate shore. The flat stones of the beach at Oakville, described on a previous page, do not come from rock on the shore above it, for the shore is of clay; but they drift, it is thought, from a rocky ledge a short distance to the east, extending a little way out into the lake, over which the water is always white.

It is possible, however, in this particular case, that the beach-stones come from beneath the water: for the banks of the stream here, about two miles back from the lake, show, down to the bed of the stream itself, thick beds of shale with thin beds of corrugated, or "ripple marked," limestone between them; these beds of both kinds extend, undoubtedly, beneath the lake; so that the oval stones may be only the beach-worn, or beach-moulded, remnants of the fragments that the waves have broken off from the beds of limestone beneath the water, and washed up on the land above.

a

SPITS. Currents, in drifting along a coast, do not follow all its indentations, but cross, often in a somewhat curved line, to the opposite side; as they do so, the sand and pebbles that they are washing along with them, drop in the deeper water at the mouth of the indentation and build up a tongue of land parallel to the course of the current, thereby partly cutting off the water within from that outside. Point aux Pins, on the shores of Lake Erie, is a "spit" of sand, about nine miles long, formed in this way, the little bay, or the harbor, of Rondeau being thus cut off from the lake. Fig. 124 shows one of these sand spits, at the western end of Toronto Island; it stretches northward and would probably have reached the shore before now had not its progress been stopped by the breakwaters built to keep open the passage to the lake. The picture shows the jagged edge of the inside of the spit, a

Fig. 124. Spit, or point, at western end of Toronto Island; Toronto Bay in foreground, Lake Ontario and Humber Bay beyond spit; breakwater of western entrance to Toronto Bay just seen on right, end of spit (bare sand) almost touching it (1901).

feature found in all, while with many the end is a great hook of sand—such as Cape Cod, and Sandy Hook at the southern entrance of New York Bay.

b

BARS. Very often where a feebly flowing stream enters a body of water, the spit is thrown right across the mouth of the stream and thus forms a bar, through which the water of the stream filters, except when in full flood it may burst across for a time. Fig. 125 shows the broad bar across the mouth of the stream at Grimsby: it consists of pebbles and coarse gravel from the glacial drift that forms the shores; these the currents of the lake which set along the beach have thrown across the stream, thereby blocking it up. It has formed rapidly of late years. In the summer of 1882 only four or five feet of shingle lay between the stream and the lake. It is now a heavy

bar from which great quantities of gravel, etc., are taken away for road-making and other purposes, the storms of winter bringing in a fresh supply.

Still more remarkable is the "Beach" at Hamilton, a long curved bar of gravel that cuts off a deep indentation, Burlington Bay, from the waters of the lake of which it once formed a part. If Lake Ontario is the result of the great glacier, or of the blocking up of the St. Lawrence by the upheaval of its bed, then we must look for the origin of this bar almost back to the formation of the lake itself.

SUNKEN BARS. Where a large river with a strong flow enters the sea, a shallow, which is really a broad bar, is usually formed across its mouth, even though no delta may be built up. At New York large ships have to wait outside the bar, the "Narrows," till the water rises high enough over it to allow them to cross into the

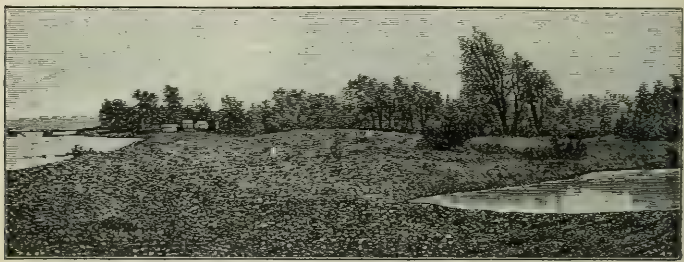

Fig. 125. Bar across the mouth of stream at Grimsby (1902): stream on the right, Lake Ontario on left; length of bar about quarter of a mile.

harbor, New York Bay; it is the same at Charleston and very many other places on the Atlantic coast. At St. John, N.B., the current of the river is so strong that no such bar is formed. There are two entrances to this harbor, one, the main entrance, at the south, the other at the west. At low water the passage to the inner harbor is seen to be a somewhat narrow channel with a strong current passing outward; to the east of the channel is a flat about a mile wide covered with mud, excepting an area of twenty-five acres or more, which is strewn with boulders, some being very large—the "foul-grounds"—a dangerous place for vessels; but on the western side lies a sunken spit of small boulders or cobble-stones, "the bar," which extends from the western shore of the inner harbor for a distance of 4,000 feet towards the main entrance, thus narrowing the western entrance. This "bar" marks the limit to which the tide, coming in by the western entrance, can carry along the stones that it washes from the neighboring shores of glacial drift (see Fig. 31) as it sweeps along them in gaining the harbor. So strangely do the currents deal with the material over which they have power!

RIVERS BEHIND BARS. A peculiarity in the action of rivers frequently attends this formation of bars and spits. Sometimes where the current from a river entering a body of water, sea or lake, is feeble and the drift current along shore is in any degree the stronger, the conflicting currents will both drop some of their sediment; the spit thus formed will be continually pushed farther forward in the direction of the drift current, and the river will be forced to abandon its former mouth (which soon gets choked up) and to flow along behind the new-made barrier, keeping open a passage to the lake, etc., whereever it can. This peculiarity is seen to a slight extent in the Don at Toronto, which bends near its mouth and runs westward a little way before entering the lake, a fact which seems to show that the sand of Toronto Island comes from the east. The Au Sable River, where it enters Lake Huron near its southern end, has the same peculiarity. The numerous "Haafs" along the southern Baltic are all due to this partial blocking up of river mouths by spits and bars; and the same occurs all along the coast of the United States from Virginia around to Mexico.

Fig. 126. The "Beach" at Hamilton: channel across between breakwaters that extend for some distance into the lake, on the right, and Burlington Bay on the left.

MUD FLATS. Not every expanse of land laid bare by the retiring tide is called a beach, for not every such one is covered with sand, shingle, or boulders. Around our Lakes, when from different causes the water is lower than usual, shallow places about islands or in curves of the shore become bare, and bake and crack in the sun, till the water once again comes back to its usual height and covers these "flats," though their grasses may still show

green above the lapping of the wavelets. What thus occurs in our lakes irregularly, occurs by the sea regularly—twice every twenty-four hours.

Inlets, whether from sea or lake, tend to fill up. The currents, whether tidal or other, do not sweep round the shores of an inlet as they do along the shores in the open; they rather eddy into them with a much slower motion, the motion near the head of the inlet being slowest of all. The coarser material borne along by the current will, as we have seen, be apt to form a spit or bar or projecting point at the entrance to the inlet; but the finer material, the mud, will be dropped only where the water has become most quiet—at the head of the inlet. Here, therefore, shallows will be

Fig. 127. Mud-flats, Minas Basin, Nova Scotia: distance from rock in left foreground to water on the horizon fully a mile. Note tracks in mud (Cf. page 3); rock is end of shelf on which cliff seen in Fig. 120 stands.

formed in lakes, and here, too, in tidal waters, and especially where the range of tides is great, will be formed the same kind of shallows, but laid bare twice a day, and called "mud-flats." Where rivers enter such inlets, the shallows and flats will grow faster, and, if there is room for growth, will be far larger than where the sediment is brought only by the currents that erode the shores.

The greatest mud-flats in Canada are doubtless those in the delta region, at the mouth of the FraserRiver, in British Columbia; for here the vast amount of sediment brought down by the river is rapidly filling up its estuary, large as it is; and though the range of the tides is not great, low water shows a wide expanse of naked mud. In eastern

Canada no other region can compare in this respect with the Bay of Fundy region. But the flats are formed almost wholly by shore erosion, not by river sediment, for the rivers, where they exist at all, are small. Except in St. John Harbor, in every place where these are found—and they are found in every offshoot—the shores or bed-rock, or both, consist of coarse red sandstone, and in some places, as at Cape Hopewell near the mouth of the Petitcodiac River, very largely intermingled with pebbles. So great is the erosion by the tidal currents in St. Mary's Bay (which has no stream at its head), Digby Basin, Minas Basin, Cumberland and Shepody Bays, that from low-water to half-tide, or beyond, the water seems almost red liquid mud. In these regions the flats are the favorite feeding grounds of that finest and largest of the herring tribe of fishes, the shad.

These shallows and flats will not always remain such, as we know; the accumulation will go on, both in lakes and in tidal waters, till the top of the water is reached; nor does the growth stop there. But in the tidal waters man does not always wait for the slow work of nature. After these mud flats have become marshes, that is, after they are so high as to be covered with water only during high-tides, and so have a growth of salt grasses on them, great areas of them are surrounded by dykes to shut out the salt water. The alluvial land thus dyked in is very fertile, almost inexhaustibly so, surpassing in this respect the "bottom lands" along the western rivers. Such dyked marshes are the famous Tantramar Marsh, the largest of all, at the head of Cumberland Bay, and the Grand Pré and connected areas, along with the Wellington and Grand Dykes, to the south and west of Minas Basin.

The mud flats, should they sink beneath the sea and in after ages be raised again above water, will be shale, with fossils of the creatures that now burrow in them or track over them in search of food. The beds of shale that our streams and lakes are wearing away with their fossils in them, are only going back again to the mud they once were.

SAND ISLANDS. Where eddies, large or small, or currents whose speed has slackened through meeting with some obstacle or through coming into conflict one with another, give rise to shallows, islands consisting wholly of sand are apt to be formed also. For here the storm waves do not advance shoreward as green ridges of water, but as white tumultuous masses "roaring into cataracts," digging up and sweeping immense quantities of sand along with them which the back-wash will not carry back; so that when the storm is over a long low rounded back of sand is seen

rising above the water where nothing of the kind existed before. Such islands may be soon destroyed again, but when once thus formed they are apt to remain. And not only so, but their presence may now change the currents so much that the islands will increase in breadth and extend their ends, as Toronto Island has done, till they reach the shore. Then the water behind this barrier island, a "lagoon," will gradually become shallower with drifting sand, till coarse water-loving grasses and weeds come, forming a marsh, and at last dry land.

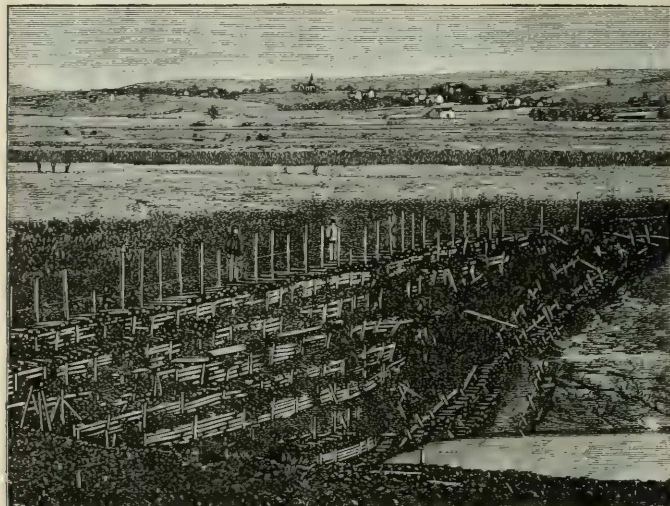

Fig. 128. Building a dyke across a drainage creek, Grand Pré, King's County, Nova Scotia; distance to background across dyked marsh, two miles; dark band in middle, an old dyke. In the bed of the creek there is a passage under the dyke so contrived that water will run out when the tide is low but will not run in when the tide is high.

Such islands, sometimes with their marshes, often not, are very numerous near the shore along the eastern coast of New Brunswick, where tidal currents are very conflicting; off the south-western end of Nova Scotia, where the along-shore currents from the sea meet the currents of the Bay of Fundy, they are a constant danger to shipping; for a new island or a new shoal may be thrown up or destroyed in a night, and so change the currents as to make charts and calculations useless. Here, on Cape Sable Island, not long ago, during a fog, one of the finest and very largest of ocean steamships, on her first voyage,

went aground on the sand and was lost, the captain deeming he was fifty miles away from the island. The currents had changed. These islands line the coast of the United States from Massachusetts to Mexico.

Sable Island, out in the Atlantic, eighty-five miles east of Nova Scotia, is one of the most remarkable of sand islands. It is a mile wide, and, with its shoals and bars, is over fifty miles long, and so low that vessels are close to it before it can be seen. "In bad weather it is a continuous line of over fifty miles of foaming breakers, producing a most terrific effect, the island seeming to shake to its foundation as the whole body of the Atlantic breaks upon it." It is a most dangerous island, and the Canadian government maintains a number of men there to assist the shipwrecked. No others are allowed to live there. Trees have been lately planted on the island in hopes thereby to fix the sand, which is now, for the most part, loose and movable.

In the Great Lakes such islands are common; we find them around Prince Edward county. Toronto Island, which has its lagoon, Ashbridge's Bay, is one of them; others are in Lake Erie, at Long Point and elsewhere, while they are especially numerous along the south-west shore of Lake Superior.

Spits and bars and sand islands all tend to straighten an indented shore, just as we have seen, that the main force of the waves is directed against any point or projection of hard rock that has been left behind in the erosion of the shore, till it is broken through and worn away, and the shore thereby has been made straighter.

LIVING BEINGS AND PHYSICAL CHANGES.

PLANTS. But it is not alone inanimate things whose working brings about such widespread changes on the earth. Living beings as well as water, frost, and heat, and other agents of weathering, have their effect upon the earth. We have seen (pages 59, 180) that plants, by their decay, give rise to acids that are highly important in dissolving rocks and in changing the character of their minerals. Geikie says that native copper was found hanging as stalactites from timbers in a copper mine in Tennessee after the mine had been closed for a few years, and fossil fish-teeth wholly of copper have been dug up in some places, the acids from the decaying vegetable and animal matter having removed all the mineral but the metal.

Sir Walter Scott tells us in The Lady of the Lake how

> "Aloft, the ash and warrior oak
> Cast anchor in the rifted rock,"

but the very rifts in which the roots, flattened and rugged

and hardened as they get, find so firm a hold, are in part at least the work of the roots themselves; and as the roots increase in size they force the rocks farther and farther apart, and either split them off entirely or thereby allow water, with its acids, to do its work of destruction. The underground walls of buildings, aqueducts, tanks, etc., are often destroyed by this means. And then, too, the presence of plants either attracts moisture or prevents it from drying up, and so the acids that their decay produces, are continually at work on the rock or soil below.

But plants do not help destroy only; they often protect rocks and soil from the action of the weather; the matted turf on a hill-side will not let the rain wash away or gully into the soil. Whoever has looked at the multitudinous roots and rootlets of bushes and grasses in a swamp where broken spots reveal them, will readily understand how they can bind the soil—keep it from blowing or wasting away, and will easily see why, shortly after a fire has swept over them, our finely wooded Muskoka hills or rounded islands stand out to the sky only as bare barren rock. Only after long years of weathering and cracking in sun and frost will they gather some little soil at their base and in the crevices and little depressions, where seeds of plants and trees—birches and pines—will lodge and grow; and these by their shelter and moisture and decaying leaves gradually push the soil farther and farther outward, as new skin grows over a burn from its unharmed borders, till once more the bare rocks are hidden beneath verdure.

And it may be added, that the minute plant-life that forms so much of the slime on the stones of our streams and brooks, effectually shields from the attacks of the running water, unless when it is charged with mud; and the seaweeds that cling to rocks in great masses at low-water mark, and extend even above half-tide, shield them from the force of the waves, and are like a cushion upon which the waves break.

Plants build up, too, as well as destroy and protect. The beds of graphite (page 18) found in our Archean rocks are thought to have been seaweed. The great deposits of coal—anthracite, bituminous, or lignite—the world over, were once trees and plants (*Coal*, page 27, etc.); and the trees and plants are doing the same kind of work still in forming beds of peat in swamps and old lakes, and even on moist level ground and hillsides. Lake Winnipeg has shore-cliffs of pure peat over twenty feet high, and in Ireland we hear of whole peat-bogs slipping from their gathering-ground on the hill-sides and sliding slowly down over the fields below, the black, liquid, slippery mud beneath greasing, as it were, their path over rock and soil.

6.

Besides, as we have seen, it is largely due to plants that flood-plains and marshes rise above the limit of the water. Their stems and roots catch and hold in place the sediment and wind-driven dust, and, when dead and decayed, form the bench on which others grow, thus continually, though slowly, raising the surface ever higher. Very marked, too, on the sea-coast in tropical countries is the effect of the mangrove; its home is the salt shallows in bays and behind spits and bars and islands. It sends up a stem out of the shallow water, from which aerial roots grow downward into the water again and fasten to the ground at the bottom, till the whole looks like a huge but ill-constructed bicycle-stand around a tree.

Here lodge all sorts of waifs and strays of the water—driftwood, leaves, sediment, shells and animal remains of many kinds; for such warm, sheltered waters are a paradise for alligators, fishes, crustaceans of various kinds, and birds, the reeking mass when laid bare at low water being most offensive. These swamps are abundant around Florida, in Western Africa, in the Bermudas, and many other tropical regions.

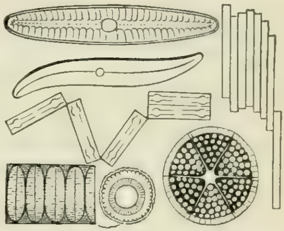

Fig. 129. Siliceous skeletons of diatoms, much magnified.

7 A curious very minute little gelatinous water-plant called diatom, having only one cell, and living on the water, not attached to the ground, forms for itself an extremely thin skeleton of almost pure silica. These exist in cold seas in vast masses and form the food of multitudes of fishes, especially herrings; it is their presence in shallow waters that make these so valuable as fishing grounds, and they sometimes are in such dense masses that they give the water a yellowish tinge and keep the nets from sinking. They are found in both fresh and salt water, and when they die they sink slowly to the bottom, where their skeletons form beds, some of which are known to be thirty feet thick. Such beds are found in the strata of all ages. "Infusorial earth" or "tripoli powder" is the name this material goes by in commerce; it is used in polishing.

ANIMALS. The lower animals play their part, too, in producing changes on the earth. The common earthworms, whose little beehive mounds of the earth that they have brought up from beneath, we have all seen piled around

the mouth of their burrows, are known to work over the surface soil again and again, and thus to expose it to change from closer contact with the air and acids, thereby making it more fit for vegetable growth. Besides, these burrows let the air and rain farther down into the ground.

Moles and rabbits and gophers dig out their long galleries and bring up the soil or sand below to the air (sometimes to the ruin of crops), where it will be more quickly changed; but the burrows act as drains to surface water. Beavers, we know, build their dams across streams, thus backing up the water to form little lakes and ponds; these fill up with sediment and become at last stretches of rich alluvial land—delayed in its passage seaward. And embankments of rivers have been dug into by crayfish, so that they have given way, an occurrence known to have been the case with the Mississippi embankments. There is no need to speak of the animals that destroy vegetation; farmers know the varied insect tribe too well.

The great work of the coral polyp in our modern warm seas is well known (page 56); and we have seen (pages 4, 5) that in every age from the Archæan Period to the present, coral polyps have been equally active; every age contains its limestone rocks filled with the remains of coralline creatures, if not wholly composed of them. Besides, the chemical effect of living or dead animals on the dissolved matter in the water of seas or lakes is often highly important; the formation of the valuable mineral fertilizer called apatite is directly the result of the presence of decayed animal matter in the water.

Countless multitudes of other marine creatures, often of microscopic size, living at the surface of the water or in its depths, form their limy or siliceous shells or skeletons from the material in the water, and when dead their remains, like those of the diatoms, build up vast beds on the ocean floor; they are doing it now as they have been doing, the rocks show us, from time immemorial.

MAN. Man's commission from the first was to "subdue" the earth—to make all its products and all its powers contribute to his necessities or conveniences. "Civilization" is only another name for this subduing. Man does not work by instinct or impulse, like the lower animals, but by reason, and hence his ways of subduing the earth vary as need requires. So long as he kept the savage state—lived as the wolf does or the bird, on other animals or fruits—there was no subdual: the earth was wild, untamed. The first step was taken when he tried to make nature in any way do as he wished; he started to cultivate the ground. How much has followed from that first step!

Civilization arose in the east,—in China, India, Persia, Mesopotamia, Egypt—all dry regions for the greater part;

and so it is no wonder that in all these we find, from the first dawn of history, there were artificial streams dug to carry the water from the rivers to places which the water would not reach. "The rivers of Babylon" of the psalmist were doubtless some of the irrigation canals with which that flat region abounded, and whose remains, dry or swampy, are often still to be seen. India from very distant times had its irrigation canals and its vast artificial lakes or storage tanks, almost comparable to the one lately completed (1902) at Assouan in Middle Egypt. The British authorities are now clearing out and extending these old works and making new ones, so that some rivers, such as the Mahanadi, in Orissa, which in the rainy season widely flooded their lower course, now can hold all their water, the great dams along their course serving the double purpose of checking floods, as do our lakes, and of keeping a supply of water for the dry months. We know what this irrigation means in western Canada and the United States: how the torrents in the rainy season, which would otherwise tear up and wash away the ground, now flow into great tanks or basins, whence the water is drawn off by sluices to fertilize fields far below.

Then when large cities grew up a constant and abundant supply of water was needed, and so aqueducts were built, into which whole streams were often turned. Rome built them at an early date, but far earlier still were those of Etruria, sometimes gigantic in size, so that we call them "cyclopean," as if they were quite worthy of Polyphemus and his kin. Wherever the Romans went in later days they built these aqueducts if needed. Jerusalem had them. They are not an invention of to-day.

Hercules, the myth says, fought with the river-god, Achelous, and broke off one of his horns; the conqueror gave it to Ceres, the goddess of agriculture, who (in pictures) has carried it ever since, filled with grain and fruits and flowers. Does not this point to early efforts to control the flow of water by throwing it into one channel? The Achelous river has a large delta, now, unhappily, very swampy, but formerly cultivated. May not the judgment and efforts of the people have stopped up one or more of the shallow distributaries that used to flood the country, and by turning the water into one channel increased its current and thereby deepened its channel? Modern engineering does this, in a way, at the mouth of the Mississippi and elsewhere.

We read that the lower town of old Rome used to be flooded whenever "the too-complaining Ilia" could prevail upon her husband, Father Tiber, the river-god, to avenge some slight done to her by mortals; but the Romans built the great drain, or sewer, the Cloaca Maxima, which carried off the water. Excavators at Nineveh, Babylon, Jerusalem, and elsewhere, often come upon the remains of ancient drains still perfect. So our modern underdrains and sewers are no new thing, although we dig them to "reclaim" bogs and marshes, and even lakes.

Man interferes with the flow of water in other ways. He builds great embankments along the course of streams so as to prevent their waters from spreading over the surrounding regions. He thus checks the building up of flood plains, but prevents disaster to himself, and hastens the river-sediment on to the sea. He builds such embankments against the sea itself—"Scoops out an empire and usurps the shore." We even straighten rivers; Toronto has straightened the Don for half a mile, putting in wooden banks. Then we build sea-walls, and piers, and breakwaters; we have hydraulic mining; our "power companies" force waterfalls to turn machinery to generate electricity, driving machines, lighting buildings, streets, etc.

But, further still. From earliest times, when the ark was built of "gopher wood," and the "cedars of Lebanon" were in high demand, and Tyre was famous for its "lumbermen," trees have been cut down for man's use. But often with disastrous results. The mountains along the south of Europe, in Dalmatia, the Tyrol and elsewhere, are now barren rocks, for the trees have been cut down and the soil has been swept from the hills by wind and rain. Our forests here in America are in danger of a similar fate. Happily alarm has been taken; we are planting trees on treeless prairies, and setting out shrubs and trees and sowing grasses on sand dunes and barren wastes in hopes, often fairly answered, of confining the drifting sand.

And finally, we build up at times, too. The refuse from our great cities, from our mines and cuttings, fill up hollows and shallow waterfronts, thereby forming new deposits.

In all these ways, and more too, such as by wells, artesian and others, man, while subduing the earth, interferes with the action of its forces, sometimes helping to destroy, sometimes to build up.

Our earth is the scene of change; the various forces at the surface are engaged in undoing what the forces beneath the surface are engaged in upbuilding;—rain, frost, heat, running water, winds and waves, tear down what upheaval and volcanic action raise up; while in the depths of the sea the wreck of the land is again being fitted by ocean current and by busy life, to become firm land once more.

CHAPTER VI.

THE OCEAN.

THE OCEANS AND THEIR FLOOR.

The Ocean, the great mass of salt water of the globe, is the goal of all our streams; they pour their waters into it, and commit their loads of sediment, visible or invisible, to its care; their work is done. But yet we shall see this is not the end after all; for "in the circle of eternal change" the water will be sent back for a new burden, to do more work, while its former load will be spread out beneath the sea, to form new land-masses in the far future, which again will have to be torn down and brought back.

The Ocean has always been a mystery, and our ignorance of what its waters conceal, has given room to poetic fancy to fill it with "full many a gem of purest ray serene," with "emerald halls" inhabited by an almost human race, lacking only the soul, the immortal part. Very little was known accurately about the bed of the sea till the British government sent out in 1872-76 the famous "Challenger Expedition," equipped with every scientific appliance, in charge of eminent scientific men. This gave a vast amount of accurate information about the sea in every way. Since then almost every civilized government has done some similar exploration and thereby added to what the "Challenger" had given before.

THE OCEANS. As has been already pointed out (pages 49-51, 54), the extent of the water-surface of the earth, or the "hydrosphere," far surpasses the extent of the land-surface, the former being about 148,000,000 of square miles, the latter 55,000,000. The great earth-fold, the top of which forms the land-surface, is to a very great extent on one side of the earth, and this of necessity throws the water on the other side. The annexed cut, Fig. 130, shows how unequal is the arrangement of land and water ; the side of the earth which has the British Islands as its centre, contains nearly all the land, together with areas of water that occupy nearly half of it ; while the opposite side, with about New Zealand as its centre, is nearly all water (Cf. page 54). Indeed, if we take the ordinary division of the earth into northern and southern hemispheres, the former will have far the most land and the latter will be still nearly all water.

The earth-fold is very irregular in shape; it has projections great and small on all sides, and indentations great and small, and even two deep depressions; the ocean fills depressions and indentations alike. For convenience in indicating places upon the earth, we give names to these water-filled irregularities on the earth-fold,—we call the smaller ones seas, bays, gulfs, etc., giving a particular name of its own to each, as Gulf of St. Lawrence; but to the larger ones, on account of their size, we give the name of ocean—Antarctic, Pacific, Indian, Atlantic and Arctic—although we call the whole mass of water by the general name of "the ocean" also. But it must not be forgotten that the real ocean is the great mass of water in the south; the Pacific is a huge triangular piece of this, extending northward having Australia, New Guinea and other islands with Asia on one side, and the Americas on the other, and terminating in almost a point. The Indian Ocean is only a northward swell of the southern ocean, between Australia and Africa;

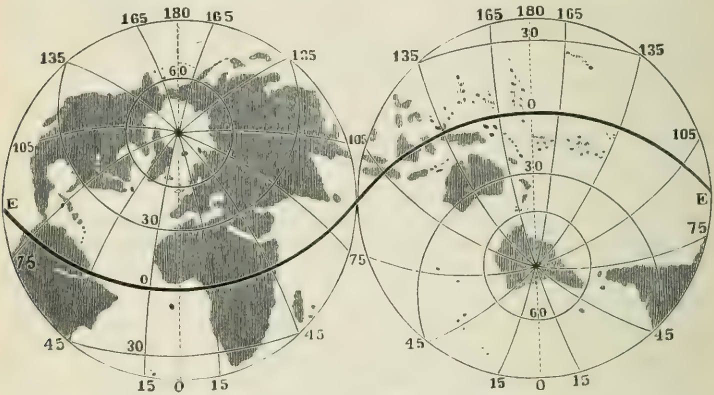

Fig. 130. Land and Water Hemispheres; the double-curved line EE is the Equator.

the Atlantic is a huge arm of the same, stretching out north between the Americas on one side and Africa with Europe on the other, till it terminates in a basin, the great gulf that we call the "Arctic Ocean," from which there is a sort of narrow back-entrance into the Pacific, a mere thread of water, Bering Strait.

THE PACIFIC. The boundaries of the ocean are in some respects artificial, not natural. The southern limit of the Pacific, Atlantic and Indian Oceans is usually given as the Antarctic Circle, south of which is the Antarctic Ocean; some geographers give the parallel of 40° south as their southern limit, beyond which is the great Southern Ocean, a preferable division; while the northern boundary

of the Pacific and Atlantic is given as the Arctic Circle, beyond which is the Arctic Ocean. The other boundaries are more or less natural.

The Pacific at its broadest, along the equator, is about 10,000 miles wide, and, though variously estimated, has an area of about 68,000,000 square miles, or approaching to half of the water-surface of the earth. A marked feature of its western side is the long strings of continental islands, Japan, etc.; these to a great extent shut off from the main ocean wide expanses of water, which in consequence differ from it in temperature, deposits, and marine life, both animal and vegetable. It has countless islands also, mainly coralline, but with very many volcanic. Some of these latter form oceanic chains, rising abruptly from great depths in the sea. The range of which Hawaii is one, is 2,000 miles long, and rises from a depth of 17,000 feet to a height above the ocean of 14,000; while in the southern Pacific is another chain known to be over 5,000 miles long. The islands are, for much the greater part, within the tropics and on the western side of the ocean. Here a band of islands and submarine plateaus, from 1,500 to 2,000 miles broad, extends from Farther India south-easterly past Australia to New Zealand, and even beyond; while another, but far narrower, is thought to exist, running from Japan south through the Ladrone and Caroline Islands to join this one. The depth of water on the plateaus varies from six fathoms between New Guinea and Australia to over 1,500 fathoms. But this band contains some deep expanses, the Coral Sea, Banda Sea, Celebes Sea, and others, where the water reaches a depth in places of fully 2,500, and even 3,000, fathoms, while just beyond the Fiji Islands the deepest "deep" known exists — 5,155 fathoms; close to the east of Japan and the Kurile Islands a depth of 4,600 fathoms is met with. Some geographers think that the existence of these two plateaus, together with another that extends west from Patagonia for about 2,500 miles, shows that there is probably a continuous plateau from Farther India and Japan south-east to Patagonia. Away from the islands and plateaus the depth of the Pacific is comparatively uniform, the average being given as 2,500 fathoms.

THE ATLANTIC. This ocean, the best known of all the oceans, especially the northern half, is much smaller than the Pacific; its narrowest part, between Greenland and Scotland, is only 800 miles wide, it is only 1,700 between Sierra Leone and Brazil, and about 5,000 from Spain to Florida. The area is about 33,000.000 square miles. It is markedly free from islands, except in its broadest part, where the West Indies shut off the Caribbean Sea and Gulf of Mexico from its waters. As noted elsewhere, most, if not all, the Antilles are volcanic, but the Bahamas and Bermudas are wholly of coral, no other rock being anywhere found. These rise out of very deep water, so that it is thought this coast must have been sinking for a long time, otherwise no such masses of coral could have been formed. The greatest depth of the Atlantic yet found is to the north of Porto Rico, where a sounding of 4,561 fathoms has been obtained. A plateau (Map, Fig. 132) lies in the central Atlantic, following its curves, so far as is known, from about 40° south latitude to about 50° north latitude, where it ends in the "telegraph plateau," between Ireland and Newfoundland. The depth of water over this is less than 2,000 fathoms, while in the basins to right and left it often reaches 3,000. Then, as we have elsewhere seen (page 49), an elevation much above the general depth of the bed of the ocean, lies between Great Britain, Iceland and Greenland. The average depth is probably near 2,000 fathoms.

INDIAN OCEAN. This body of water is only the swelling up of the great southern ocean between Australia and Africa, where it is about 4,500 miles broad. As observed elsewhere, the existence of an irregular plateau, which extends from Madagascar in a general direction to India, and from which rise Bourbon, Seychelles, and other islands, is thought by some geologists to prove the existence of a former land connection with India; the water on this often lies not over 1,000 fathoms deep. Another plateau, on which stand St. Paul's Island and Kerguelen Land, lies between South Africa and Australia, at a depth of about 1,500 fathoms. The average depth of this ocean is about 2,500 fathoms. The islands are in the western part; the larger ones, excepting Madagascar, are mainly volcanic, but the Maldive and Laccadive are of coral.

ARCTIC. We know the outer rim of the Arctic Ocean, with its numerous islands north of Canada and of Europe, but of the inner part we know nothing, although the most persistent efforts have been made to reach it. The pack-ice blocks all entrance "into that silent sea." Pack-ice is not fresh-water ice, but salt-water ice, which requires a temperature of 28° F. to form. At first such ice is "sludge," then when strong enough to hold snow, it is "brash," when it cakes, it is "pancake-ice," this when thick and covering a wide area, is "floe-ice," and when its bounds cannot be seen it is "field-ice." It is the floes crushed together and piled up, often to a depth of a hundred feet, that forms the pack-ice, a mass that does not melt away, but apparently goes on accumulating, portions breaking off and drifting away as "floe-bergs."

Icebergs come down into the North Atlantic from the east coast of Greenland and from Baffin Bay; for here cold polar water flows southward and brings the bergs with it. No bergs come down the coast of Norway, for here the warm currents from the Atlantic set northward and pass east for some distance along the northern shores of Europe and Asia. It is the return current, the cold one, in the west that brings the ice down southward. Until fuller knowledge of the currents of this region exists, it seems hopeless to get through or far into the pack-ice. The winds, too, are exceedingly variable, and these influence the movements of the ice.

THE ANTARCTIC. The Antarctic seems even more effectively closed than the Arctic; for a great ice-barrier from a hundred to two hundred feet thick seems to rim the whole region. In 1841 Sir John Ross, who in this expedition spent four years in explorations, sailed along the ice-barrier for 450 miles; there was not a single break in it and it was calculated to be fully 1,000 feet thick from top to bottom. Sir John, who reached the farthest point south, 78° 11′ S., that had been yet attained, gave the name of Victoria Land to the land he discovered.* Some think that

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*Since the above was put in type, the news has come from the "Discovery" expedition to the Antarctic, under Capt. Scott, that by means of sledges 82° 17 was reached in the southern summer of 1902-1903,—207 nautical miles beyond any point previously attained.

it is a great continent, covered with an ice-cap, others regard the land as consisting only of islands. Glaciers exist on this land (Fig. 117), and glacial drift is abundant; it has its volcanoes, one, Mt. Erebus, is 12,400 feet high, and a companion near by, Mt. Terror, is 10,900 feet high. The fact that icebergs are often seen aground here far from land, goes to show that the continent, if it exists at all, is low-lying. Bird life seems abundant. Borchgrevink, who wintered at Cape Adare, in Victoria Land, in 1891-2, was made aware of the approach of spring by the arrival of countless thousands of penguins, a sea-bird that cannot fly, coming from, he knew not where, and making their way, "waddling," across the rough ice, to which he could see no limit, even with his glass.

CONTINENTAL SHELF. By reference to the map (Fig. 132) it will be seen that everywhere around the continents the water is shallow; in some places this shallow border is broader than in others, but except at the mouths of some great rivers, such as the Amazon and Hoang-Ho, it does not appear to be over a hundred miles broad. It is the "continental shelf"—that part of the great earth-fold which rapidly flattens to pass upward into land. From the outer edge of this, which lies, strangely, at an almost uniform depth of a hundred fathoms, the floor of the sea drops downward quite rapidly, at the mouth of the English Channel, as we have seen, 10,000 feet in a distance of ten miles.

It is along the top of this shelf and on the deep-sea slope that the sediment brought down by streams is spread out. On the inner and shallower side the coarser and heavier sediment, both from the streams and the shore-waste, settles; and so it is sand-islands, not mud-islands, that the waves sometimes build up.

Beyond this sand area, and in deeper water, lies the region of mud. The mud is usually blue from the presence of so much organic matter, animal and vegetable, and giving off an odor of sulphuretted hydrogen, especially when slightly heated. It changes to a greyish color, however, as the organic matter decays. This is the great belt of marine life; here are the feeding grounds of

fishes, both of those that feed on diatoms or other vegetable organisms, and of those that prey on the others. Beyond this region is the area of limestone, where the limy matter held in solution is deposited.

It is on the top and along the flanks of this continental shelf that, according to some geologists, originate great earth movements, which result in the forming of mountains along the coast. For the vast beds of sediment that must gather there in the course of ages become so heavy that the strata which support them beneath, slowly give way and sink, and as the pressure on the flanks is in part exerted sidewise, a great and continuous push is given to the shoreward strata, and they in consequence rise. (Page 10.)

Where the shelf-deposits are especially great, in the region of great river estuaries or important eddies, they are known to give way and form great sub-marine land-slides.

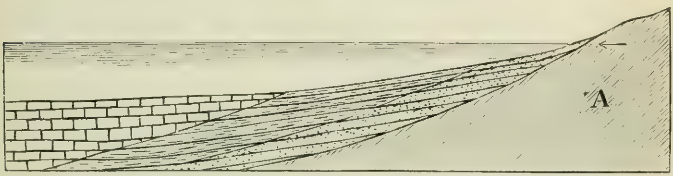

Fig. 131. Diagram of deposition of sediment. A, the underlying rock with beds of sand resting on it; on the sand lie beds of mud, beyond which are beds of limestone. Courtesy of G. W. Wilson.

Telegraph cables are thus often broken, and at times buried so deeply under the mud that they cannot be drawn up. This has occurred at the mouth of the Congo. Japanese scientific men say that these land-slides are the causes of some earthquakes.

In the shelf-deposits will be embedded the remains of plants and animals of all kinds—the shells of shell-fish, the crusts of crustaceans, the bony skeletons, teeth and scales of still others, along with those of the inhabitants of the land—insects, birds and beasts. Unhappily, the remains of man will be only too abundant also; for pleasure-seekers along the beach or in the light sea-craft that skim through the quiet water near the shore, and "those who do business in the great waters," or who grapple with each other in the

0–100 fathoms.

100–2000 fathoms.

2000–3000 fathoms.

FIG. 132. CHART OF O


80
40
0
40
60
40
20
0
20
40
80 from 40 Greenwich 0 Longitude 40 East
3000–4000 fathoms.
4000 fathoms and over.

IC DEPTHS.

deadly fight, all supply hosts of victims to "the all-devouring sea."

The remains of plants will be there too; sea-plants of all kinds—sedges and other grasses, seaweeds, kelp, dulse, Iceland moss, or any other, and the innumerable varieties of land vegetation, from oaks to mosses, fragments of which our streams bear down to the sea.

THE DEEP SEA.

But the deposits of the deep sea are different; it is no longer the sand and mud of the continental shelf, though the passage from one kind of deposit to another is never abrupt, but gradual; there is always a zone where the two intermingle. In the deep, but not the deepest, sea the deposits are almost wholly beds

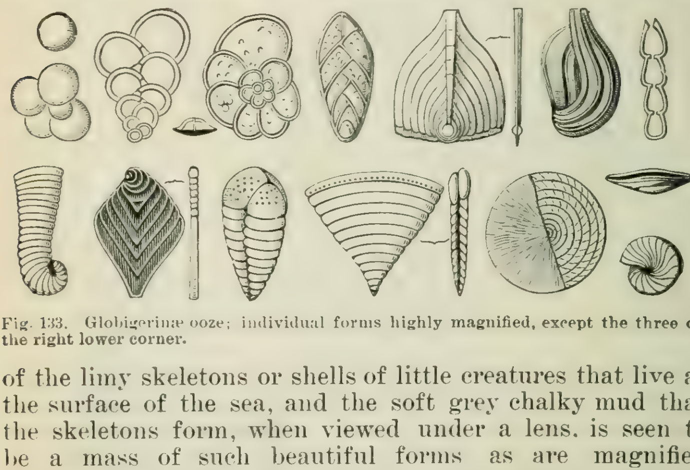

Fig. 133. Globigerinæ ooze; individual forms highly magnified, except the three on the right lower corner.

of the limy skeletons or shells of little creatures that live at the surface of the sea, and the soft grey chalky mud that the skeletons form, when viewed under a lens, is seen to be a mass of such beautiful forms as are magnified individually in Fig. 133. This mud is called the *globigerinæ ooze*. In some parts of the sea the ooze is made up of the skeletons of other minute, but not dissimilar, creatures, and in the cold seas the ooze is composed of the siliceous skeletons of diatoms. (Fig. 129.)

A marked change of deposit comes with the deepest sea—2,900 fathoms and over. Here the sea-floor is covered with a deposit of red clay that under the microscope is seen to be composed almost wholly of sharp angular grains

of various minerals, quite different in appearance from the bruised and rounded grains that make up the mud of the shoreward deposits. They are mainly of volcanic origin—volcanic dust and minute fragments of decayed pumice stone. For we know what vast quantities of dust volcanoes throw out, the greater part of which must settle down on the ocean; and much of the pumice stone falls there too, and floats about for months or years before sinking or decaying; and explorations have revealed the existence beneath the water of great numbers of volcanic peaks that never appeared above the surface, but that must have poured out their contents into the sea; and if the innumerable coralline islands rest upon a volcanic foundation, as some think, we can readily see whence comes the volcanic material that forms this deep-sea deposit, and that is plentifully found in the other marine regions as well.

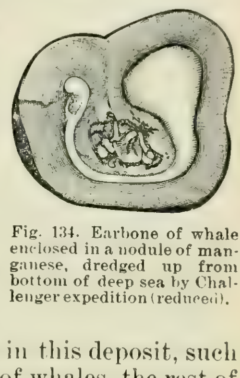

Fig. 134. Earbone of whale enclosed in a nodule of manganese, dredged up from bottom of deep sea by Challenger expedition (reduced).

But some of this red clay is believed to come from the wholly decayed globigerinæ and other skeletons; the chemical elements, especially carbonic acid, in the deep-sea water destroys the limy matter of the skeletons and leaves the formless remainder to mingle with volcanic clay.

There are hard animal remains, too, in this deposit, such as the teeth of sharks and the ear-bones of whales, the rest of the bony frame having been all dissolved. Curiously enough, these bony remains often form the centre around which minerals gather, so that little lumps of manganese which have been dredged up, on being cut open, often reveal a tooth or an ear-bone within them. Some of these bony remains are perfectly free from encrustations of any kind, and therefore must have been a shorter time on the sea-floor than the encrusted ones; and as the growth of the deposits and of the encrustations is inconceivably slow, the mineral-surrounded remains must have been deposited ages ago. Indeed, many of the remains of whales belong to species long extinct. This and the fact that no such

beds as are now forming in the deepest sea, have been found among known strata, seem to prove that the bed of the ocean has always been where it is now, and that the stratified rocks, with their fossils, belong to deposits that were laid down on the top or on the flank of the continental shelf.

It will be readily inferred from what has been said, that though the ocean depths possess hills and hollows, there are no crags, no sheer cliffs and angular projections, though steep rises where submarine volcanic cones exist, there must be. The deposits cover, or round off, or fill up everything; there is no frost, no fretting streams, no dash of waves, down in its quiet depths. What erosion the tides and other currents may cause, is confined to the inner side of the continental shelf.

WATERS OF THE OCEAN.

SEA LEVEL. We say that "water seeks its level"; that is, it will continue to run down hill till it reaches the lowest place, and there it will accumulate, every point of its surface being equally distant from the centre of the earth. The bed of the ocean is the lowest part of the earth's surface, the part nearest the centre; and therefore all the water of the earth is trying to reach the ocean, where every point on its surface is equally distant from the earth's centre.* This would actually be the case were the earth everywhere of the same density, were the lithosphere everywhere even, and consequently the water of the same depth above it everywhere, were there no winds and currents, and were the air always of the same height and the same density. None of these things are so, and consequently the water is really nowhere level, even though the surface may be smooth.

We know that on our Great Lakes, when a strong easterly wind is blowing, the water at their western end gains on the land, but falls back again when the wind dies away. A continuous easterly storm does great harm on the Atlantic coast, for it floods with water the low-lying districts of town and country about the shore, breaks through dykes around alluvial marshes, destroys wharfs, and does damage in many ways. The force of the wind drives the water before it, or drags it along, piling it up along the coast. Tidal currents in shallow water are masses of water moving forward with greater or less speed, and the water in the places that have high-water is many feet higher than where there is low-water—in the Bay of Fundy over fifty feet. Other currents have a similar but less marked effect. The effect of winds or

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*It will, of course, be seen that a line drawn along the surface of the sea must be a curved line passing around the earth; a straight line would extend outward into the heavens.

currents on water may be seen by blowing gently along the surface of some water in a long dish, or with the hand by pushing the water in a long trough: a little wave will run along the water from end to end, being higher at the end where it is stopped than elsewhere.

Then the air on an average presses upon the water (and the land, too,) with a weight of about fifteen pounds to a square inch. Sometimes, as the barometer shows, the air over a region becomes less dense, and therefore does not press so heavily on the water, which will at once rise higher in such a region than in the surrounding ones—not to stay very long so, however. We also say that every mass of matter attracts every other mass of matter in direct proportion to its density, and in indirect proportion to its distance—the heavier a body is the more it will attract another, and the farther away it is the less it will attract. Very many experiments will prove these facts. It is found that if a plumb-line be lowered from the top of a high vertical wall, the lower end of the line will be a little nearer the wall than the upper end is. The wall attracts the weight on the plumb-line. And what seems most strange is that the water of the Indian Ocean where it is nearest the mighty mass of the Himalaya Mountains, at the mouth of the Indus, is over five hundred feet higher than it is at the southern point of India—so great is the attractive force of the huge earth-ridge to the north, of which the Himalayas are only the front. And the same thing is true elsewhere on the earth, but not on so great a scale.

It is thus plain to be seen that there really can be no such thing as a "sea level," though we must speak as if there were.

SEA-WATER. From what has been said in former pages, we know that in the water of the sea there must be mineral matter and chemical elements of very many kinds—of all kinds that exist in the ground or in the air, including gold, silver, copper, iron, and other metals. We taste sea-water (sometimes when it is much against our will to do so), and find it not only salt, but bitter. In the Bahamas, in Portugal, France, Spain, and other countries, where salt is obtained from evaporating sea-water, salt is but one, though the chief one, of the products; the thick "mother liquor" that drains from the salt into a receptacle for the purpose, contains many another substance, and it is these that give the bitter taste.

The Challenger brought to England a multitude of samples of sea-water, taken from the ocean in many different parts of the world, and from depths ranging from the surface to a thousand fathoms below it. These, on being carefully analyzed, showed about $3\frac{1}{2}\%$ of salts of different kinds, the other $96\frac{1}{2}\%$ being pure water. Of these different salts the percentage was as follows:—

Chloride of sodium (common salt)	77·758
" " magnesium	10·878
Sulphate of " (Epsom salts)	4·737
" " calcium (gypsum)	3·600
" " potassium	2·465
Bromide of magnesium	0·217
Carbonate of calcium (lime)	0·345

In addition to these there are carbonic acid, oxygen, nitrogen, and common air. Oxygen is more abundant in the surface water and carbonic acid gas at the bottom.

These gases are needed for the support of life in the sea, both of plants and animals. The air gets entangled in the water through the dashing and breaking of the waves, and soon dissolves into its separate gases; then, as there is a continual circulation of the sea-water, not only around on the surface, but an upward and downward circulation as well, the gases are carried downward to the lowest depths of the ocean. Fish by means of their gills extract the oxygen from the water and give off carbonic acid gas, and thus breathe as well as do land animals, even in the deepest sea, though before the Challenger did its work it was thought the abysmal depths of the ocean were lifeless.

It must be borne in mind that, if the nebular theory (page 6) is correct, the water of the ocean and its mineral matter of all kinds existed in the gaseous state in the nebula, as well as did the material of the land. The various compounds, such as water, lime, and salt, were all formed as the cooling process went on, and they thus took from the atmosphere a very great part of those elements that by themselves are destructive of life, such as hydrogen, chlorine and carbonic acid gas, the compounds, strange to say, being often essential to the support of life—the great end of material creation.

We cannot tell whether the sea is growing salter or not, or whether the amount of mineral matter of all kinds is increasing in it or not; it would require a long series of years and most accurate scientific observation and experiment to find this out, and it is only of late years that facts are being carefully collected and examined. The sea is wide, and as yet little is known of what exists in its depths; and it seems from the nature of things that little will continue to be known.

We know, however, that rivers are bringing to the ocean vast quantities of solid matter every year, and that although vast quantities of water are taken away from the sea by evaporation—at least as much as rivers and rains pour into it,—the solid matter is not evaporated, but stays behind in

the sea. A great deal of it is deposited on the sea-floor; sea-plants and sea-animals must take up very much of it in one way or another, to form their hard parts at least; and, as we have just seen, mineral deposits of various kinds, formed by chemical union in the water itself, are spread plentifully over the bottom.

When we think that vast deposits of salt exist the world over, that there are even mountain ranges of salt in many places, Spain and near the Dead Sea, for example, we might conclude that the sea must have been far salter in geologic ages gone by; but when we see what is taking place in the Great Salt Lake, in the Caspian and Dead Seas, and elsewhere, the thought comes to us that just such bodies of water as these, with similar dry surroundings, existed in those far off ages and gave rise to these deposits of salt.

Not all parts of the ocean are alike salt. Naturally the parts where evaporation is greatest are the saltest, and those where there is the most rain or snow, and where rivers are most numerous, are the freshest. In the Atlantic the saltest water is between Spain and the Gulf of Mexico, and south-western Africa and Brazil; in the Pacific, west of South America. Such land-locked seas as the Mediterranean, Red Sea, and the Persian Gulf, are the saltest of all; while the Polar oceans, Hudson Bay, and the Baltic, are the freshest, for the evaporation is least and the amount of fresh water in different forms is greatest.

TEMPERATURE OF THE SEA. Naturally we should expect that where the heat of the sun is greatest the water of the sea is warmest, and to the greatest depth. This is really the case to some extent. In the torrid zone the surface temperature varies from 76° F. to 80°; at Aden, in south-western Arabia, 84° has been registered. In the cooler parts of the temperate zones the temperature of the surface-water is between 44° and 54°, not varying more than 15° between winter and summer. We may see by this fact why the climate of islands and of maritime countries varies so little in temperature throughout the year in comparison with inland regions, such as Ontario and the West. In the north Pacific, which is exposed only to a slight inflow of

polar water, a summer temperature of 70° is found. In the Arctic Ocean the temperature of 30°, or even 28°, is common. As 28° is the freezing point of salt water, pack-ice is then formed, which, unless broken up by storms and driven southward into warmer seas, never melts.

The heating power of the sun is found not to extend very far beyond a depth of 100 or 150 fathoms. Everywhere in the ocean at an average depth of 500 fathoms, the temperature is almost uniformly 40°, but, strange to say, in the torrid zone this temperature is found at a depth of 300 fathoms. After 40° is reached the decrease takes place more and more slowly to the bottom, where the usual temperature is about 32°, though in the South Pacific 31° has been registered, and even lower than this at some other points.

Between the surface and the dividing line of 40° the temperature varies a great deal; sometimes it changes slowly and regularly with increasing depth, sometimes very rapidly and irregularly, especially in the torrid zone.

MOVEMENTS OF THE OCEAN.

Enthusiastic sea-bathers have been known to bring to their inland homes bottles of the salt-water, with the intention of regaling themselves at times with its sea-odor. But usually one experience of the odor after the cork has been taken out of the bottle, leaves no desire for another. The water smells as if putrid. Just as our blood circulates in our veins in order that it may all pass in succession through the lungs, where it is oxidized—brought into close contact with the oxygen of the air—so the waters of the sea need to be kept in continual motion in order that they too may be oxidized—purified, made able to support the multitudinous life within them. Only a few sea-animals, those of the whale and seal families, breathe directly from the air; the others all get their oxygen from the water, and it is only from the continual tossing and fretting of the sea at its surface that air gets mixed with the water; and only by continual circulation, or movement, is the water, thus aerated, carried through the whole mass of the sea from top to bottom.

In the Black Sea, whose bed seems to be undisturbed by any movement, the deep-lying water is foul, and when brought to the surface gives forth as offensive an odor as stagnant pools. The shallow lagoons behind spits, and bars, and islands, load the air with impure fever-breeding vapors, and doubly so when their reeking beds are laid bare by the retiring tide. Coleridge's picture of the great calm in the "Ancient Mariner," though the glamour of poetical genius is thrown over the description, does not go beyond observed fact, and, indeed, in some respects, does not come up to what has been experienced. A long period of dead calm in hot latitudes gives opportunity to the minute, frail, gelatinous organisms to increase in masses beyond all bounds, and the gases that arise from the water taint the air far and near. A motionless sea would destroy life on shore. The tides, by exerting their force chiefly in long, narrow bays and inlets, where oceanic circulation does not reach, not only enable vessels to go where otherwise they could not (Figs. 139, 140), but keep the water in strong, even violent, commotion.

More than this. The heated water of the tropics is carried by oceanic circulation far up into the polar regions, giving off its heat as it goes, and thus making the climate of the countries along whose shores it moves, far warmer than it otherwise would be. The southern point of England is in about latitude 50° N.—the same as that of Winnipeg;—but flowers bloom the year round in the Isle of Wight and in Cornwall; and grain is raised by the inhabitants of Iceland and far within the Arctic Circle in Norway, while either ice covers the whole land in corresponding regions in North America, or only stunted willows and alders exist.

WAVES. We look at a sheet of perfectly still glassy water: a breeze comes along, the surface darkens and ruffles, and soon little ridges of water are seen stretching away at right angles to the course of the wind. It is the friction, or rubbing, of the wind on the water that raises the ridges. The wind does not have the same effect on ice, or wood, or rock, because the particles of these cohere closely one to another, while the little globules of water do not cohere very closely, and therefore readily yield to anything that presses upon them: the wind does this, and they readily yield to it. In a large expanse of water, such as one of our Great Lakes or the Ocean, the water under a heavy wind rises into great waves or hills of water, separated by deep hollows

or troughs. In the open Atlantic, during a storm, waves as high as 43 feet have been observed.

Often in fine weather and a quiet sea great magnificent swells of water move majestically onward, scarcely, if at all, breaking the surface. They are the *ground-swell* that comes from regions hundreds of miles away where storms have occurred.

But the waves in deep water do not move before the wind as a vessel does, the whole vessel going onward; but a wave is a mass of water that suddenly rises in a spot and sinks back into it again, while the force, or impulse, that raises it passes on to do the same to another mass. Thus, if we watch a stick being tossed up and down by the waves, we see it keep up the same average position on the water; but we notice, however, that as the wave advances the stick moves toward it, rises to its crest, drops down on the back of the wave, and then moves forward to the original place. Of course if the wind breaks the crest of the wave the water will be thrown forward and settle beyond its original position. The water seems to oscillate, to shake, or move backward and forward, something like a tree during fitful gusts of wind, though the real movement is undoubtedly circular.

In shallow water, however, where the wave-producing force has not room or material, as it were, wholly to spend itself in making a wave, it exerts its unexpended part in driving forward the wave it does make. As the lower part strikes the bottom and drags along it, the wave rises higher and higher, its back gets flatter and flatter, and the front steeper and steeper, till the crest, no longer able to stand upright, tumbles over in a foaming curl of water in front, rushing up the beach, and leaving it

"Covered with waifs of the tide, with kelp and slippery seaweed."

When a wave, which out in deeper water is running at a sharp angle with the shore, approaches the shore, the inner end reaches shallow water first, and being retarded more and more by friction with the bottom, the whole wave swings round as if on a pivot, and runs almost, if not quite, dead on shore. As the wave is rushing on and up the beach, there is below the surface a backward set of the water, called the "undertow," a source of danger to incau-

tious bathers and to the boat that rides ashore on the crest of a wave.

SPEED OF WAVES. It has been calculated that a wave 100 feet long (from the crest of one wave to that of the next) in water 100 feet deep, travels at the rate of fifteen miles an hour; one 1,000 feet long in water 1,000 feet deep, at the rate of forty-eight miles; whereas another 10,000 feet long and in water 10,000 feet deep will sweep onward at a speed of not less than a hundred and fifty-four miles an hour. It will require water *thirteen and three-quarter miles deep* in order that a wave may travel 1,000 miles an hour.

EARTHQUAKE WAVES. We can readily understand how the shock of an earthquake occurring beneath the sea gives rise to waves (page 109, etc.). Such waves are usually of enormous size, and when they roll on shore the destruction they produce is often appalling. It was these waves that caused the terrible loss of life during the earthquake that accompanied the destruction of Mt. Krakatoa, in the Straits of Sunda, in 1883. In 1854 the town of Simoda, in Japan, was destroyed by a succession of waves that rolled ashore during an earthquake. In twelve hours and twenty-eight minutes after the shock in Japan, the earthquake waves were felt in San Francisco, a distance of 4,527 miles.

TIDES. In our Great Lakes the water, though varying in height in different seasons, according as rain and snow have been more or less abundant, does not change its level at regular intervals; but at the sea-shore the level is seen to change regularly; there is a continual change; only for a space of about fifteen minutes four times in about twenty-five hours is there a stand-still; and the difference between the height of the highest ordinary "high-water" and the lowest ordinary "low-water" is in some places fifty feet. The interval, too, between high-water and high-water is quite regular, being twelve hours and twenty-six minutes.

These changes were, of course, known to all dwellers by the sea from remotest times; and in ancient books there are found many suggestions as to their causes, some of which show much accurate observation and connect them with the moon. Not till the great fact of the universal attraction of matter was discovered could the true cause be known. Sir Isaac Newton, whose name will forever be associated with all that is great in science, was the first to put forth the theory regarding the tides that is now held by all scientific men, though it has not yet been fully worked out in all the details of its application.

CAUSES OF TIDES. We know that every object in nature attracts, or tends to draw toward it, every other object in nature—"every particle of matter attracts every other particle of matter." The earth and moon, being objects in nature, therefore attract each other, and, like other masses of matter, with a force directly proportional to their size. Had the earth and the moon suddenly sprung into existence with their full power of mutual attraction, they would have rushed directly toward each other, the moon going eighty miles to the earth's one, for the moon is eighty times smaller than the earth. But, from whatever cause, both had another motion than what their attraction would give them, a straight-on motion; they could not obey both, and the result was a movement between both, a peculiar kind of circular motion about each other.*

If we fasten one end of a piece of lath, say, to a block of wood and the other end to another block, there will be a point somewhere along the lath where we may tie a string and lift all up, the two blocks perfectly balancing; if the blocks are of equal weight, the point will be half-way along the lath; if of different weights, it will be nearer the larger block; indeed it may be wholly inside the edge of the larger block. Such a point as this where the balancing takes place is called "the centre of gravity." Now, one may give the blocks so balanced a whirl and they will turn round and round this "centre of gravity."

Attraction is just such a bond, for it fastens the earth and moon together, though not in such a stiff way as the lath does the blocks; but the earth is so much heavier than the moon (the earth is 8,000 miles in diameter, the moon 2,160), that the centre of gravity is about 1,000 miles inward from the earth's surface, and so in revolving the earth and moon will turn around this point.

In Fig. 135 E represents the earth and M the moon; G, inside the earth's circumference, is the point about which all balances, while DF, the line passing through G, is the axis about which all revolves—once in about 28 days. But it must be borne in mind that the earth is

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*Many interesting details in this discussion must be omitted, such as the resolution of forces, attraction of other planets on earth and moon, the peculiar character of the motions, resulting from mutual attraction, etc.

rotating on its axis, AB, all the time at the rate, on the equator, of 1,000 miles an hour; and so the particle of the earth that forms the point G, or the row of particles that forms the axis DF, is changing every instant, whirling off in its own particular circle.

When the roads are wet we see little lumps of mud flying off every part of the rapidly turning tire of a carriage wheel; if our two blocks of wood are not securely fastened together by the lath, they too will break away as we turn them, and fly off; and as we whirl around our head a stone tied to a string, we feel a constant pull on the string. It is a law in nature that a body in motion will keep on in motion forever, and in a straight line, unless prevented by some other force. The mud sticks to the tire of the wheel and gets the wheel's motion; but the constant endeavor to go on in a straight line at last loosens it from the tire, and it goes its way—only to be seized by another force, attraction, and brought to the ground. It is the same with the blocks at the end of the lath, and with the ball at the end of the string. In this last case we *feel* the continual pull. The force that thus tends to keep a body going on in a straight line from where it gets its motion, is called the *centrifugal* (centre-fleeing) force; the other that turns aside, or deflects, this motion, making the body to turn around a centre, is called the *centripetal* (centre-seeking) force. If one of these, say the first, should get the stronger it would destroy the other, and the moving body, the ball for instance, would fly off; if the second grew the stronger, the body would fall to the centre—a quick jerk on the string would bring the whirling ball to the hand. So it is seen that the balance between bodies revolving around a centre depends upon the exact equality of the forces at work.

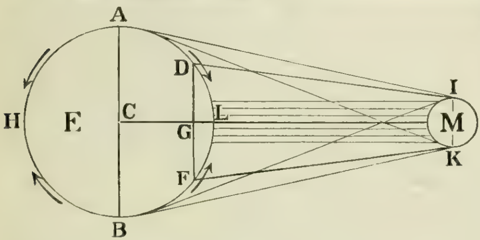

Fig. 135. Diagram to illustrate tide-producing forces Diameter of M (the moon) ¼ of E (the earth).

Now, the earth and the moon in revolving around their common centre of gravity exactly counterbalance as a whole—the centrifugal and centripetal forces are equal. But the moon, while attracting the whole earth from side to side and rim to rim, attracts a little more strongly the side, or hemisphere, nearest to her; half way between the two surfaces lies the line of average attraction, the diameter ACB of Fig. 135. If the earth were a solid body this difference would not be noticeable; but the outer part is water, and water moves to the slightest impulse given it. In the cut the parallel lines from M represent the attraction of the moon exerted from all parts of the moon straight toward the earth; the other lines represent attraction not so exerted.*

*In reality only along the heavy parallel line MLC is the attraction wholly direct; but within this "parallel area" beneath the moon, the angular attraction is so little that it may be neglected.

The attraction of the moon has no other effect on the water in this area of parallel attraction than to make it a little lighter than elsewhere; *it cannot raise the water up in the slightest degree;* if it could, then the moon's attraction would be stronger than the earth's. Outside of this area, however, or wherever the attraction is angular, the case is different. There, it is plain, some little of the moon's force is exerted inward toward the area of parallel attraction, and as the water cannot go straight down to it, so to speak, on account of the solid earth beneath, it slips along the bottom toward the area. This horizontal force, as it may be called, thus *draws the water from the whole of the rest of the hemisphere towards this area.* The force is greatest about half-way between the parallel area and the points A and B, where the average attraction is, and hence where there is no force moving horizontally. *The water thus coming together through this horizontal attraction constitutes the tides;* there will be a "high-water" in this area.

Again, the centripetal and centrifugal forces are in their total effects equal; yet as the former force beyond the line A B is less than that on the other side, the centrifugal force thereby becoming stronger, the water on the opposite face of the earth, viz., AHB, will tend to fly off; but as it cannot do so any more readily than the moon can lift the water beneath her, it will glide toward H, the area directly opposite the area of parallel attraction in ALB. There will thus be an accumulation of water here also—the "high-water" that is always opposite the high-water under the moon. Then as the rotation of the earth on its axis brings every portion of its surface more or less within the direct influence of the moon, or brings the moon to the meridian of that place, every place will have two high-waters every twenty-four hours and fifty-two minutes, separated by two low-waters.

If the earth were standing motionless with the moon revolving around it as a centre, there would be only one tide a month at any place, for there would be no centrifugal force to make a tide on the opposite side of the earth from the moon. If the earth did not rotate on its axis, but only revolved (not *rotated*) with the moon around the common centre of gravity, G of Fig. 135, there would be two tides a month at each place, one when it was under the moon, and one when opposite. The daily rotation on its axis is needed for the two daily tides.

SUN'S TIDES. The sun and the earth have a mutual attraction as well as the moon and the earth, but the principle and action are precisely the same in both. But though the sun is vastly heavier than the moon, yet its immense distance from the earth makes its tide-producing power much feebler than that of the moon.

SPRING AND NEAP-TIDES. Yet the sun's influence on the water of the ocean is marked. In Fig. 136 let 1 represent the earth with the moon tide ABCD alone on it, swelling out toward opposite points D and B beneath the moon, which is toward M. Then let 2 be the earth with the moon tide ABCD as before; but now the attraction of the sun, which is toward S in the same line with the moon, is joined to that of the moon; the sun's tide AECF, a comparatively small one, is thus added to the moon's, and the result is a much higher tide than that of the moon alone. Such a double tide is called a "spring-tide." But through the movements of the planets the sun

comes gradually to act at right angles to the moon, as seen in 3; and now not only is the sun's tide taken away from the moon's, but some of the water that was drawn from A and C 1 to B and D, is drawn away again to A and C; the moon's high-tide, therefore, at B and D 3 is so much the lower — lower than in 1. This relative position gives the lowest high-tides and the highest low-tides of the moon -the "neap-tides." Of course the progress of the sun from over F 2 to over A 3 is gradual, and so, in the language of the sea-shore, the tides keep "nipping off"; then, when A is reached, the progress is again toward a straight line with M — the tides keep "springing" till the sun stands over D, when, being in line with the moon, the two attracting bodies will again act in concert; but this time the centrifugal force of one will act with the centripetal force of the other, the result being again spring-tides, just as when the two centripetals were acting together. The continued progess of the sun brings it finally in about 28 days round to the point where it and the moon again join their attractive powers. The tide-producing forces of the sun and moon act in concert at the new and full moon, but the highest tides occur only on the day after, as the lowest occur a day after the moon quarters.

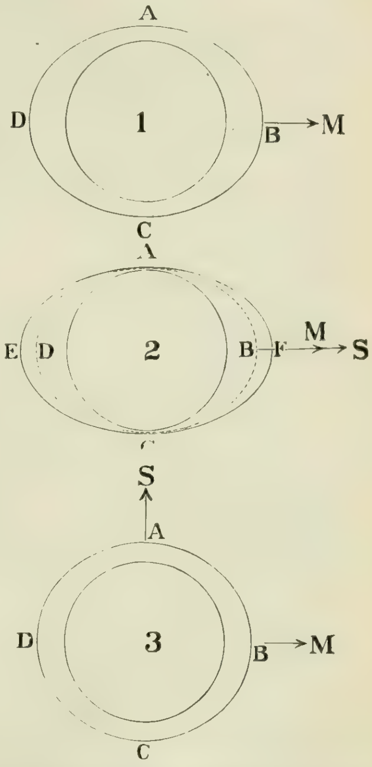

Fig. 136. Diagrams of neap-tides; 1, moon-tide; 2, sun-tide on moon-tide; 3, moon-tide and sun-tide separate.

UNEQUAL SUCCESSIVE TIDES. The moon's path, or orbit, is not in the same line, or plane, with the earth's equator, but crosses it, twenty-eight degrees to the north and south alternately. The moon is thus directly overhead, or at its "zenith," no farther north than the parallel of 28°, and at a corresponding distance south of the equator. Fig. 137 represents the earth with the moon tide on it; the crest, or highest point of the tide, is at A, the moon being in its zenith toward M at 12 o'clock at night; the crest of the corresponding tide will be at C on the opposite side of the earth, 28° south latitude; low-tide will be along the line (or circle) GH,

all round the earth, half-way between the two crests. Now, an island situated at A will have the full height of the tide, while one situated at B, on the same parallel of latitude but on the other side of the earth, will have a much lower tide, for the crest of the tidal wave is south of the equator, and only the outer limb, so to speak, of the tidal wave reaches B. The latter will have its high high-tide in twelve hours more.

Thus we see that two successive tides are not of the same height. But while this inequality of successive tides is so very marked in America, and many other places, it scarcely exists in Western Europe, the reason being unknown. Actual observation, however, shows that the inequality is less in reality than in theory. When the moon is at its zenith on the equator, there is no inequality anywhere in the same or corresponding latitude, as a figure similar to Fig. 137, but with its crest at the equator, will readily show.

MOON'S VARYING DISTANCE.

Nor is the moon always at the same distance from the earth. The tide-producing force of the moon (and of the sun, too,) varies as the cube of the distance, so that when the moon is nearest the earth (in *perigee*) this force must be considerably greater than when the moon is farthest from the earth (in *apogee*). Thus the tides are considerably higher when the moon is in perigee, and so it is very clear that, whenever the attraction of the sun and of the moon are in the same line, and the moon is nearest the earth, and the earth is nearest the sun (in *perihelion*), the range of the tides will be greatest; they will be very high tides; and conversely when the moon quarters, and at the same time is in apogee and the earth is farthest away from the sun (in *aphelion*), the range of tides will be least—they will be very low tides. (See "The Tides," by G. H. Darwin; Houghton, Mifflin & Co., Boston).

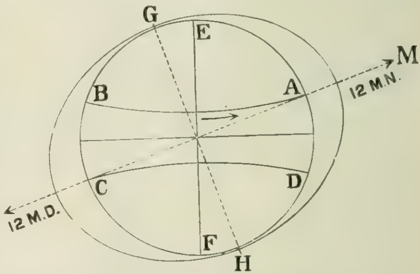

Fig. 137. Diagram to illustrate inequality of two successive tides: 12 M.N. = midnight, 12 M.D. = mid-day.

OBSTRUCTION TO TIDE-ACTION.

From what has been said above about the tides, it would be inferred that the crest of the tidal wave is always directly beneath the moon, or wherever the moon is highest; that high-water occurs at any place when the moon is on the meridian of that place, above the horizon or below it; and that, under tidal influences, the shape of the earth is a shifting ellipse with its longest diameter pointing to the moon. All would be true were there no hindrances.

Suppose the earth without land, and the water everywhere at least thirteen miles deep—that being the depth needed for a wave to travel at the rate of 1,000 miles an hour. Then, in the equatorial regions, where the earth is 25,000 miles in diameter, and where the moon is in the zenith always at some place, the tidal wave would flow around the earth once in twenty-four hours and its crest always point to the moon. Then suppose the water were only six miles deep; it is plain that the tidal wave could not keep up with the moon, but must lag behind it, and continue to do so more and more, and that the shallower the water the more the wave would lag; and consequently it would not be high-water at a place when the moon would be on the meridian of that place; or if such should happen, the high-water would not be due to the moon at that actual time, but to the moon at some previous time—its impulse had been given to the water and left to act.

But the actual ocean is nowhere thirteen miles deep; indeed, it averages scarcely a quarter of that, so that the deepest sea is shallow compared with the requirements of the great tidal wave, and hence the tidal wave must forever lag behind the progress of the force that raised it.

A curious result follows from this. In unobstructed water thirteen miles deep the two opposite tidal waves would change the sphere-shape of the earth slightly to that of an ellipse with one of its ends pointing to the moon; but the retarding of the wave by shallow water would wholly prevent this; indeed, it has been demonstrated that just the converse is true—the shortest diameter, the side of the ellipse, is directed toward the moon.

But the shallowness of the ocean is by no means the worst hindrance to the action of the tidal force. The great masses of land thrown across the course of the tidal wave, the innumerable islands and the varying depth of the sea, all interfere to an indefinite extent and make the problem of the tides one of great complexity. Only in the Southern Ocean, where there is little or no land, can the tidal wave have anything approaching free action. Here, it is thought, the tidal wave in the short longitudes may keep up with the moon, and as it follows round and round the earth there, it sends off branch waves into the Atlantic and Pacific, which travel northward, spreading or extending in

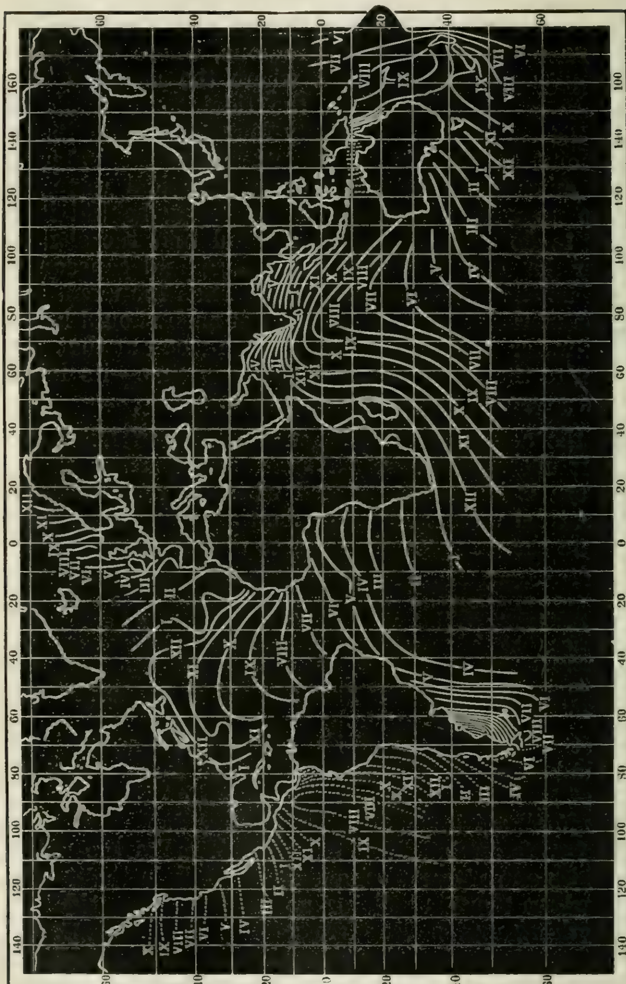

Fig. 138. Cotidal Chart, showing hourly advance of tidal wave from the Southern Ocean into Indian, Atlantic and Pacific Oceans, the varying trend of crest, its crowded character in places, etc.

all directions into the various bordering waters at rates of speed and at heights such as the depth of the water, the form of the coast, and obstructions of many kinds, will permit. And it need not surprise us to find, as is actually the case, that there are three high-waters in the Atlantic at the same hour, or that places in the same latitude or longitude, or lying near together, should have high-water at very different hours. (See cotidal chart, Fig. 138.)

The utter complexity of the problem of the tides is further seen in the facts that all heavenly bodies exert an attractive influence on the earth; differences of atmospheric pressure cause differences in tides; winds increase or decrease them; currents interfere with them, as do also great rivers; there are daily tides and monthly tides, and tides of

Fig. 139. High-water, Port Williams, Nova Scotia, about three miles from Minas Basin. River same as shown in Figs. 98, 101.

longer periods. In short, the influences that cause or obstruct movements in a mass of matter with so slight a cohesive power as water has, are, on our earth, almost innumerable.

HEIGHT OF TIDES. In the open ocean, away from land, it is impossible to tell how high the tides rise; but at isolated islands the range is found to be from one to three feet only; hence it will be seen how slight is this influence of the tides on the shape of the earth, though the weight of the great mass of the water forming the tidal wave has been proved to have an important influence in this respect. At Sable Island, 85 miles off Nova Scotia, on the edge of the continental shelf, the range is only four feet, there being no difference between spring and neap tides; at Halifax the greatest range of spring-tides is seven feet six inches, the mean, or average, range for spring and neap tides being six feet.

HEIGHT IN BAYS.

We have seen that a wave is not a mass of water moving forward; its water rises and then falls back under an impulse given it. But when the wave reaches shallow water it does become a moving mass, rushing upon the shore and up the beach. It is the same with the tidal wave. In the open ocean the tidal force is a mighty impulse that must extend to the bottom of the deepest sea, and when it nears land it turns the water it influences into great currents, moving masses, modified in numerous ways by the shape of the coast and the shape of the sea-floor.

Fig. 140. Low-water, same place, and from same point as preceding picture; water at foot of pier, one foot deep; height from bottom of river to point shown in Fig. 139, 45 feet, actual measurement.

But it is in long, narrow bays, with wide mouths and steep shores, and with long mud-flats at their heads, that the fullest display of tidal energy takes place. The Bay of Fundy affords one of the best illustrations of this in the world. Its mouth, from Cape Sable to Maine, is about 200 miles wide; its shores are everywhere steep; at its head, where it divides into two branches, it is about twenty-five miles wide, and in the branches there are extensive mud-flats (page 245). The current here is very strong, and the tides increase in height as they advance up the bay. At

Westport, near the mouth, in Nova Scotia, the range of the tides is over 20 feet; at St. John, further up, it is 29 feet; near the head of the Basin of Minas, it is 50 feet; while some say, though actual measurements do not bear it out, that at the head of Cumberland Bay it is 70 feet.

THE BORE. The rising tide nowhere appears as a common wave, though we speak of the "tidal wave"; at most it is perceived as a current, and then only close to land. The "bore," however, shows the extreme effect of the retarding of the tidal wave, though the precise conditions of its occurrence have not been fully ascertained. It always occurs where the range of tides is considerable. It is the rapid advance of the tidal wave up a stream, the mouth of which, at low-water, is shallow for a long distance, or exposes mud flats. The

Fig. 141. Great tidal bore at mouth of Petitcodiac River, head of Cumberland Bay, New Brunswick. Height, 5 ft. 4 in.—Geol. Survey of Canada.

front of the wave, as it pours roaring over the shallows or flats, is steep, owing to retarding, but it is not a perpendicular wall. There are two or three, or even more, rushes of the water, the first being the largest and most dangerous to craft that happen to be caught in the shallows or grounded on the flats. The greatest bore known occurs at the mouth of the Tsien Tang Kiang River, in China, where the shallows are very extensive. One observed there in 1892 (page 66) had a height of twelve feet at the first rush, followed by another rush of eight feet. The largest one known in America is at the mouth of the Petitcodiac River, at the head of Cumberland Bay, New Brunswick.

TIMES OF HIGH-WATER. As a result of the manifold influences that determine the time of high-water at any place, it may be said that every sea-port has its own time and range of high-water. These have been fixed at all important sea-ports by long-extended

observation, only to a comparatively small extent by mathematical calculation. The time of the occurrence of high-water at a place after the moon has passed its meridian, is called "the establishment of the port." The oceanic waters of Eastern Canada show the extreme variability of high-water in adjacent places. Sable Island, a very narrow sand-bank, which, with its shoals, is somewhat over fifty miles long, has high-water on its north side an hour later than on its south side. On the south shore of the Bay of Fundy high-water invariably comes sooner than on the north shore—it is high-water well up toward the head of the bay when it is high-water at St. John, while at Campobello Island, at the very mouth of the bay, it is sometimes high-water forty-five minutes earlier than at St. John, and sometimes nearly fifteen minutes later.

In the Gulf of St. Lawrence there are many peculiar tidal phenomena. The tidal wave enters by Cabot Strait, and, while the main wave follows the channel, which is from 200 to 250 fathoms deep, north-west to the St. Lawrence River, a branch wave goes south-west through Northumberland Strait, and another directly west, striking the coast of New Brunswick. This last is turned aside and in part flowing back along the north shore of Prince Edward Island, meets the tidal wave coming from the east along the same coast, with the result that high-water is everywhere at about the same hour all along the north shore of the island. Still going eastward, or rather north-eastward, this wave meets a low-water from Cabot Strait near the middle of the gulf, with the result that around the Magdalen Islands, though there are tidal currents, there is little or no rise and fall of the water. Precisely the same thing occurs in New Brunswick, on the part of the coast of Northumberland Strait between Shediac and Richibucto; here the deflected wave meets the low-water before the wave coming west through the strait arrives there. And finally, at Charlottetown, the tides are both later and higher than anywhere else in the strait, east or west.

In estuaries or deep, narrow bays the interval between low-water and high-water is less than between high-water and low-water. So great is the force with which the tide ebbs in the Bay of Fundy that its mouth at low-water is considerably below the level of the sea.

OCEANIC CURRENTS.

CURRENT-PRODUCING CAUSES. The wind, as we may see in every little pond, by its friction drives the water before it; if we set a basin of water before an open fire the heat of the fire expands the water nearest it, which flows off, forming a little current round and round the basin; if we dip some water from a pond the water around flows in to fill up the hole thus made; if we put a piece of ice in a basin of water and then drop in around the ice a little coloring matter, we see the cool colored water go to the bottom, creep along it and then up one side of the basin: cold water sinks, thus making a current.

In the great ocean all these causes, and others, are at work producing the manifold and often perplexing movements to which the waters of the sea are subject.

EXISTENCE OF CURRENTS.

In the open sea it is not easy to determine if a current exists. We know that West India plants have been cast ashore in Great Britain, Norway, and even Iceland; that abandoned vessels —derelicts—have been found again far away from where the crew left them. These must have been either blown off by the wind or drifted by a current.

Between the years 1885 and 1887 the Prince of Monaco set adrift between the Azores and Newfoundland over 1,700

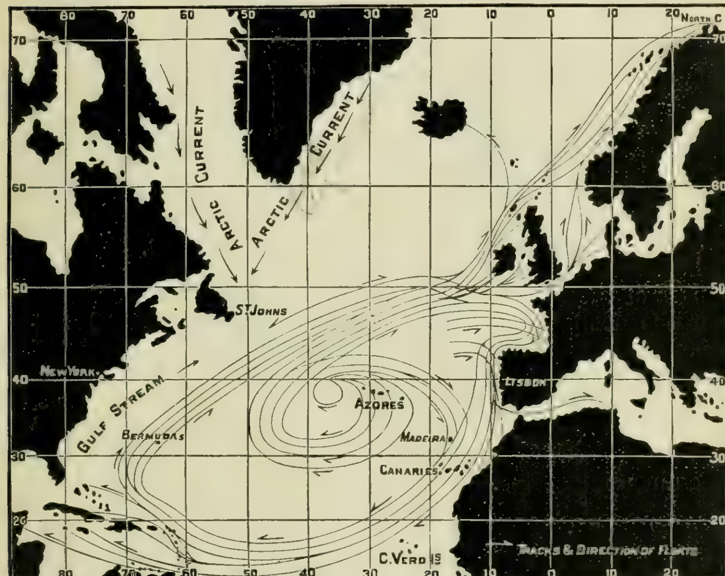

Fig. 142. The Prince of Monaco's chart of the currents of the North Atlantic as determined mainly by drifting floats.

floats, some of which were made of copper and glass, containing a request that the finders should forward them to the nearest authorities, who would send them to a given place, with a statement of the time and place of finding. Of these 225 were recovered within five years, and from the information so obtained it has been fully proved that there is a great circular current in the North Atlantic, from which

a branch streams off past the British Isles and Norway, and that an inner whirl exists west of the Azores, part of which at least circles round and round indefinitely. Here were picked up the floats that had been longest adrift, five and one-quarter years; they had been put into the water here and had remained drifting round and round.

The thermometer, too, will show the existence of currents; for if a vessel that has been sailing in the same latitude in water of, say 50° F., rapidly passes into water of 60° F., and then, after a time, again passes into water of 50° F., it is certain that at least a warm layer has been crossed: such could not keep its place unless it were in motion. By this means the Gulf Stream and other currents have been traced.

It is by the thermometer, too, that we know there are currents at the bottom of the deep sea; for though icebergs have often been seen moving against the current on the surface, a proof that there was a current lower down moving in an opposite direction, yet the icebergs extend only a short distance downward. The thermometer shows a thick mass of the coldest water everywhere covering the bottom of the deepest sea, even under the equator. Such water can come only from polar regions, and hence there must be some kind of vertical circulation as well as a horizontal one; but our real knowledge of the currents of the sea is practically confined to the waters neighboring on the coasts, and to the North Atlantic—in short, to the great oceanic commercial routes.

GREAT CURRENTS. On both sides of the equator, but broader on the north than on the south, is a great current flowing westward round the earth, except where land interferes. It is best known in the Atlantic, where it is from 300 to 400 feet deep, and moves at the rate of less than a mile an hour. On reaching South America it divides, one part flowing south along the coast till it gradually eddies eastward, forming the southern half of the great South Atlantic circular current, and then sweeps round again to its starting place, and again flows westward; the other part flows along the north of South America, and on reaching the West Indies divides, one division entering the Gulf of Mexico and re-issuing as the Gulf Stream; the other, turning northward, forms the western side of the North Atlantic circular current. In the Pacific a similar division takes place when the current reaches the western side. One division branches off north-easterly past Japan and sweeps round the Northern Pacific back to the starting point, while

the other, in part, turns south past Australia to join the South Pacific circular current, and in part makes its way through the shallow waters among the islands into the Indian Ocean, whence, along with currents of the Indian Ocean, it goes west to Africa, turns south, some running as a swift current through Mozambique channel, the rest, gradually curving back eastwardly, becomes the southern part of the whirl of the Indian Ocean.

In the Southern Ocean, where there is little or no land to interfere, the water flows in a continuous easterly drift round and round the earth; farther south, as also in the Arctic Ocean, little or nothing is known of the currents.

Between the northern and southern parts of the equatorial current there is a somewhat narrow counter current running back toward the east.

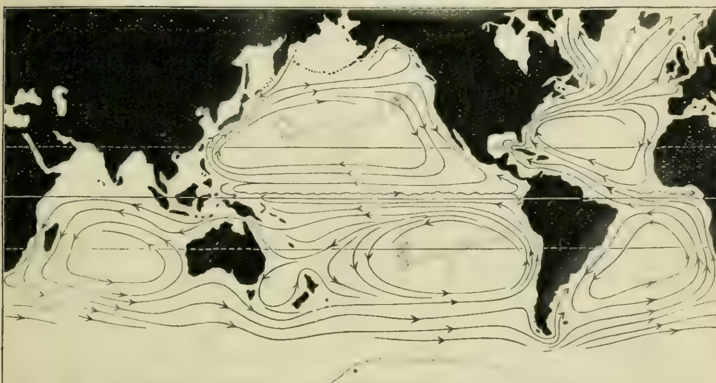

Fig. 143. The great oceanic circulation: arrows show direction of currents. Whirls in North and South Pacific and Atlantic: eastern drift of Southern Ocean joining the whirls at north, the Atlantic sending currents to the Arctic, which sends return currents: reverse currents along equator.

CAUSES OF OCEANIC CIRCULATION. Scientific men are not yet agreed as to the causes of oceanic currents; some hold that, while the surface drift of the oceanic water is caused in part by the prevailing or periodical winds, the movement as a whole is the result of the unequal heating of the water in the equatorial and the polar regions. The water of the equatorial region, being exposed to greater heat, expands, and thus becoming higher, though ever so little, than the water farther away, flows off down a little hill, as it were, toward the cooler water, and finally to the polar regions. Here the great

cold contracts the water, which thus becoming heavier and pressed upon by the inflowing water on top, slowly sinks and creeps along the ocean-floor back to the equatorial regions again, where it rises to take the place of that which has been heated and forced to flow off, itself to repeat what it had previously done, thus completing the circle of flow.

Others hold that though differences in temperature may produce a slight effect, yet, on the whole, oceanic movements are caused directly or indirectly by the prevailing winds. The equatorial currents move in the same direction as the prevailing winds, and change with their changes; the currents of the Southern Ocean move eastwardly continuously with the constant western winds of that region, while in the Northern Indian Ocean the change of direction of the periodic winds, or monsoons, is followed by a change of currents. The quiet eddies, the sargasso seas, which are known to exist in the centre of the great oceanic whirls, and in which are collected and retained vast expanses of seaweeds, drift-wood, etc., the homes of innumerable multitudes of sea-creatures, are just where lie the great regions of atmospheric calms.

INDRAUGHT CURRENTS. In every case where the currents bend away from the continents, there is, as might be expected, an indraught or reverse current from the polar regions, for the set of the water from the shore will leave a slight depression there which the water from a region not under the influence of a preventing current, will flow into and fill, rising from below as well as flowing in as a surface current. Thus a cold current runs down along eastern North America, called the Labrador Current, and even crosses the Gulf Stream, to run along the western coast of Cuba. These are the currents that bring icebergs, fog and cold and raw weather. None come down the west of Europe, for the North Atlantic current strikes it; but one sets up the western coast of Africa, and a third along south-eastern South America. There can be but slight cold currents in the North Pacific, for it is almost shut off from the Arctic. But everywhere there seems to be a general set of the south-polar water northward, in part as these indraught currents, and in part—by far the greater part—as deep bottom currents.

WARM CURRENTS: GULF STREAM. In some parts of the sea there are currents much warmer than the surrounding water. They are readily distinguished by their darker color, as well as by their temperature, and their line of separation from the bordering waters is strongly marked. They have their origin in shallow enclosed seas in the equatorial regions, where their waters are heated much beyond the usual temperature of the open sea.

Of these warm currents the Gulf Stream is the most important. It issues from the Gulf of Mexico, between the Bahamas and Florida, with a speed of from 80 to 90 miles a day, and a temperature varying from 83° F. in summer to 77° F. in winter. Its breadth at Florida Strait is 50 miles, and its depth about 350 fathoms. It keeps close to the coast till near Cape Hatteras, when it trends eastwardly, and, broadening out and becoming quite shallow, is lost in the northward drift of the warm equatorial water.

The mild climate of western Europe, so much milder than that of corresponding latitudes of eastern North America, is not due to the Gulf Stream, as has been so often said, but, as the chart, Fig. 142, shows, to a great branch of the warm North Atlantic whirl, which passes north-eastwardly to the Arctic.

The cause of the Gulf Stream is undoubtedly two-fold. The water of the Gulf becomes greatly heated in its confined and, for the most part, shallow basin, and tends to flow off; at the same time it is pressed upon from the east by the great mass of the equatorial current; the result is that the heated water is forced out of the Gulf through the only channel possible, a very narrow one, between Florida and the Bahamas, for the greater part of the opening north of Cuba is practically closed by the coral "banks" of those waters. The winds, as is sometimes said they do, cannot possibly have anything of importance to do with this quick-flowing current.

The Kuro Siwo, flowing from the island-filled seas west of the Philippines and New Guinea, and past Japan, is another warm ocean current; it is not so warm nor does it flow so fast as the Gulf Stream. Beyond Japan it turns east and joins the Pacific circular current.

CURRENTS OF LAND-LOCKED SEAS. Seas such as the Mediterranean, Red and Baltic, are not connected with the great system of oceanic circulation. The evaporation in the Mediterranean is greater than the quantity of water it gets from its rivers, especially in its eastern part; the level is therefore lowered and a surface

current sets inward at the Strait of Gibraltar. But below this inflowing current is another of the salter and heavier Mediterranean water flowing out, for whenever a heavier fluid comes into contact with a lighter one the former penetrates into the latter. The Baltic has more fresh water flowing into it than evaporates; hence its discharge into the North Sea is comparatively fresh. The salt water of the Atlantic flows into the latter as a surface current, then dips beneath the fresher water, and thus flows on into the Baltic. In the Caspian Sea there must be a flow from the fresh region at the north, to where the evaporation is so great in the south, as must also be the case between the west and east Mediterranean.

In enclosed seas currents are created by the winds, and flow as the wind blows, except where reverse currents exist.

CURRENTS IN GREAT LAKES. In our Great Lakes, besides the general set of the water towards the outlets, there can be only wind-currents. In all, the prevailing currents are toward the east; but in all, too, there are reverse currents toward the west, for the same reason as in the ocean—by the piling up of water on a lee shore, or the driving of the water away by the winds, etc. A reverse current curves round the western end of Lake Ontario, another at the west of Erie, and also in Superior, which has besides a western current at the north; one sets north in a curved way along the eastern side of Lake Michigan, and in Huron south-east, curving north-east.

TIDAL CURRENTS. In tidal rivers whose flow of fresh water is large, the fresh water continues to run down stream long after the tide begins to rise; it is the tongue, or wedge of salt water pushing its way along the bottom beneath the fresh water that lifts the river up, making it rise, not a wall of salt water from the sea that meets and checks the outward flow of river water.

The currents produced by tides are often dangerous and very perplexing, as they are very changeable. (See page 248.) Among the islands north of Scotland and off Norway the currents, especially during high-tides, and when the winds are strong, take the form of furious races, as in Pentland Frith or the "Merry Men of Mey," and often as whirlpools, like that of Corryvrecken. Where a headland separates two bays a strong current often exists. Where the Bay of Fundy divides into Minas Basin and Cumberland Bay, the water of the strong incoming tide piles itself up in a little side bay about eight or ten miles long and as many wide; the additional pressure thus caused creates a reverse undercurrent, which comes to the surface at Cape Split as a furious torrent, and rushes in short, heavy, foam-capped waves for several miles down the bay, cleaving its way through the advancing tide with a roar that, during spring tides, may be heard for over ten miles.

CHAPTER VII.

THE ATMOSPHERE.

41 **COMPOSITION, WEIGHT AND IMPORTANCE OF THE AIR.**

The one thing essential for the existence of that highest outcome of nature, Life, whether of vegetable or animal, in the sea or on the land, is the Atmosphere, the "vapor sphere" of the earth; without it there would be universal death.

COMPOSITION OF THE ATMOSPHERE. The atmosphere is a mixture of various gases, with some solid matter in the form of dust. Of the gases *Pure Air* is by far the most important, consisting of a mixture of twenty-one parts by measure of oxygen and seventy-nine of nitrogen, and forming about twenty-nine thirtieths of the whole atmosphere. *Aqueous Vapor* is everywhere present in the atmosphere, no matter how parched the climate; it is not equally diffused everywhere, nor is it always present to the same extent in the same place; naturally there is most over water and over moist regions, where evaporation is greatest, but the winds carry it far and wide. *Carbon Dioxide* (carbonic acid gas) is also present, coming from burning wood, coal, etc., from decaying vegetable and animal matter, from volcanoes, active or extinct, and other sources, and though heavier than air and often accumulating in deep hollows and other enclosed places, bringing death to whatever breathes it, it follows the law of gases and diffuses itself everywhere. *Ammonia*, so needful to plant-life, also exists, and is washed from the air into the ground by the rain. *Ozone*, a very important purifier, and thought to be very beneficial to weak lungs, is most abundant near the sea and on mountains. Other gases in minute quantities also exist in the atmosphere. The *Dust* of the air becomes visible in a sunbeam which enters through a chink into a darkened room. It comes from various sources: every fire pours smoke, which is in part dust, into the air, wind blows it from the parched ground, and the explosion of volcanoes adds its part (page 69).

IMPORTANCE OF PURE AIR. The oxygen of the air is the concentrated supporter of life, needing to be largely diluted with nitrogen in order to do its work properly. Animals on land inhale it, and in their lungs coming in contact with their blood it unites with the blood's chief impurity, carbon, forming carbon dioxide, which is breathed out into the air, where it is taken up again by the leaves of plants; in the leaves the two gases are again separated, the oxygen returning to the air, the carbon

remaining to form the woody part of the plant. In the sea the fishes, by means of their gills, separate air from the water, for it gets entangled with the water at the surface where the waves are dashing about, and the vertical circulation of the sea in the polar regions carries the aerated water down to the lowest abysmal depths.

IMPORTANCE OF AQUEOUS VAPOR. The quantity of aqueous vapor in the air is small when compared with the whole mass of the atmosphere, yet it must be very great in itself, for by far the largest part of the earth's surface is covered with water, and most of this is in the warmer regions of the earth, where evaporation is very active; and, as we have seen, evaporation is going on at all times and in all regions, no matter how dry or how cold. But the vapor would be of little use in the air did it not return to water the ground and to give drink to animals and vegetables alike; for it is from this vapor that clouds, and rain, and hail, and snow, and dew, are formed, and it is this vapor that has so much to do with our storms.

CLOUDS, RAIN, SNOW, ETC. We know that water or any other liquid dries up, or "evaporates"—turns into vapor, and we know that heat is the cause of this; but how heat does it we do not know. There is no such thing in nature as perfectly dry air: moisture is everywhere; and the warmer air is the more moisture it can hold without our seeing it. But there is a limit, a point beyond which it can contain no more: it is *saturated*. It is then that we see the smoke of railway engines, of steamers, and of tall chimneys, streaming away near the ground in long lines sometimes miles in length, not rising up in the air and disappearing as is most usual, for the air has in it all the water that it can hold, and smoke is only water-vapor with some little of other gases in it, and some particles of solid matter, carbon. And then things feel damp, and linen and cotton articles and paper are limp.

saturated

Sometimes when the air is in this state the sky is without a cloud, though not bright and clear; then clouds seem to form everywhere over the whole sky at once with startling suddenness. For somehow the air has become cooler; either cool air from far up in the atmosphere has, for some cause, settled down into the warmer water-filled mass

below, or in some other and unexplainable way the temperature has suddenly fallen, and the air has to give up some of its moisture; the aqueous vapor has, to some extent, been condensed, and we can see it in the shape of CLOUDS.

It is not needful for the air to be everywhere saturated before clouds can come into the sky. Like water, air has its currents, great and small, that flow through the surrounding air, across other currents, past them, or against them: we have all seen the dusky low-flying "scud," after or before a storm, flying far below the other clouds that are high in air, and in directions wholly different from theirs. And it is only needful that one of these currents, in any part of the sky, should get cooled past the point of saturation in order for clouds to form. Saturation does not depend on the *amount* of moisture in the air, but upon the capability of the air to hold more moisture; so it is often seen that the air is saturated, though the hygrometer, the instrument that tells the amount of moisture in the air, shows there may be far less moisture present than on another occasion when there is no saturation.

Very strange in appearance and infinite in variety are the forms that clouds take. The light, thin, feathery clouds, the "mares' tails," the "cats' paws," the ones that float in the heavens in fine weather—the *Cirrus* clouds—are high in air, five miles or more, and so must be formed of ice particles that somehow, perhaps by rising currents of air, are kept floating in those cold regions; for without something to keep them up they would settle down in the air till they came to where the air is not saturated, and then they would disappear and "build up the blue dome of air."

Then there are the *Cumulus* clouds: we see them in the late afternoons of summer and in warm summer evenings piling themselves up in great hills higher and higher above the horizon, rolling outward from top and sides as the warm moisture-laden currents of air from the heated ground stream upward and fall below the point of saturation; and we see the cloud being made before our eyes. We see them lighted up by the refracted rays of the evening sun, and when the sun is gone we see, too, a rosy glow, flush or quiver through them, and hear a dull roar coming from them. These are the "giants," our old Norse ancestors thought, who come to harm man; but man's friend, the god Thor, stands ready, and his mighty hammer flashes in lightning through the sky and falls in thunder upon the foreheads of the giants, whose roar of pain reëchoes the crash of the blows, and they pass moaning away—often, as they do so, shedding tears of rage and pain, which we, who know so much more than these ancestors of ours, call a "passing thunder shower."

The *Stratus* clouds extend in long and often broad bands across the sky; their lower part, like that of the cumulus clouds, is often sharply marked against the sky, for the stratum of air beneath is not saturated, and reaches to a strangely uniform height. These are not attractive clouds, and do not tempt us, as the cumulus clouds do, to see all kinds of fanciful objects in them—birds, and beasts, and monsters, men and women,

"aerial knights and fairy dames." From the dark, heavy, sky-concealing *Nimbus** clouds come our storms of rain and snow; they show that the cooling process in the upper air is widespread and continued beyond the point of saturation, so that now RAIN must fall.

For the temperature has fallen so low that the air is filled with floating particles of mist, or "water-dust," and these coming into contact unite into drops of water which can no longer float about, but fall earthward, gathering size as they fall. Electricity is so common in these storms that scientific men think the particles of mist are little hollow globules of water-vapor, coated, as it were, with a film of electricity, and when they unite the electricity comes together in such quantities that it falls to earth or passes from cloud to cloud and ignites, as do the sparks from an electrical machine.

In the autumn or in the spring a rain-storm often comes up that ere long turns into a *Snow-storm*, and then the bare trees and every outdoor object put on that weird, ghostly look. The cooling of the air has gone on till the freezing point has been reached, when the watery vapor turns into minute crystals of ice, those delicately beautiful forms that we all know, and as they gather into clusters they fall in fluffy bunches as snow. In winter a snow-storm does not begin with rain, for the temperature is already below the freezing point; but if in this cold state the air is saturated a further fall in the temperature will bring snow. Conversely, of course, if the fall occurs without a storm of rain or snow following, the air was not saturated.

In summer, even before the sun is down, the grass and other things out-doors begin to have a dampish feeling, which increases a little later, till the hand, when passed over them, becomes wet, and little globules of water are seen on the tips of the grass and elsewhere. It is DEW, for the ground, as the sun's heat diminishes, has given off its heat more quickly than the air, and is now colder than the air, and it cools the layers of air near it below the point of saturation, the *dew-point*, and the moisture of the air gathers at the tips of the grass, which seem to be coolest, and then on everything rough, not often on smooth, polished things, for these have no heat-radiating points. But it is only the low-lying stratum of air that is thus cooled below the dew-point, for no dew is found on tops of trees or houses. Nor is there any dew on windy nights, for the air has no time to "stop and cool off." And when clouds cover the sky, they will not let the heat pass away into the space beyond, but confine it, so that the heat the ground has given off, returns to it again.

Unfortunately for farmers and fruit-growers, market-gardeners and out-door florists, sometimes in June, and commonly in early September, on a clear night, when no cloudy blanket is over the earth and when the moon is high up in the sky, the cooling, or the radiation of heat, goes much farther than the dew-point, and the morning shows everything covered with FROST and the leaves of plants stiff and hard. And

* The classes of clouds given above are well marked types, though they may be blended in an endless number of ways. They are best studied by observation.

when the white covering melts in the increasing heat, blackened and drooping and shrivelled leaves, and flower-stalks with limp hanging heads, and dead flowers, tell the tale of destruction.

The *ice-storms* that split down our trees, tear off their branches, and so mar their beauty that long years are needed to restore it, and that work such destruction in orchards and to telegraph and telephone wires and poles, have really the same origin as the frost; the temperature of the ground is below the freezing point, that of the air is not quite to it, and as soon as the rain touches the ground, trees, fences, wires—anything that is below freezing point—it loses enough of its heat to make it freeze.

Sometimes just before rain reaches the ground it passes through a layer of air below freezing point; the rain is frozen and reaches the ground as little grains of ice—or HAIL. But the bigger lumps that fall during thunder-storms, and that newspapers and excited narrators always say are "bigger than hens' eggs," are different. They start, it is thought, as frozen rain, but are seized by strong currents of wind that carry them alternately down into a warm stratum of air and up again into a cold stratum, receiving every time a new coating of ice or half-melted snow, till, having grown too large to be carried longer, they fall to the ground.

~~SOURCE OF THE EARTH'S HEAT.~~

Although the heat of the interior of the earth may be intense, yet the surface is not perceptibly affected by it. All our heat comes from the sun.* But the sun's rays, or solar energy, do not warm the vast space, over 92,000,000 miles deep, between us and the sun; for outside of our atmosphere there is nothing for them to warm. And their direct effect upon the atmosphere, too, is very small, especially in the upper regions, for at an average distance of about 19,000 feet above the ground within the tropics the temperature is always at freezing point; beyond this the cold rapidly increases in intensity, and must be inconceivably great outside of our atmosphere.

HEATING THE EARTH.

As the sun's rays that come earthward pass through the atmosphere, the air, the aqueous vapor, the dust, reflect some of them back into space, absorb others, but let the greater part, about two-thirds, go on to the earth; here they too are for the most part absorbed, but some of them are reflected back into the

*The sun does not send out heat as a furnace sends out a hot blast when the door is opened; but it sends out a force, known as *solar energy*, that so affects the objects which it strikes that what we call *heat* is the result. This is referred to in the text as "the sun's rays"; and "heat" is used in the ordinary way rather than in the way required by the foregoing part of this note.

atmosphere, especially by the water and the snow-covered land. The few rays absorbed by the atmosphere, whether they come directly from the sun or are of those reflected back from the earth, warm it to some extent; but the greater part of the earth's heat comes from the heat produced in land and sea by the action of the sun's rays upon them.

If we put one end of an iron rod into a fire, we soon feel the end we hold in the hand growing warm, and our hand will grow warm too—the heat passes, or is conducted, along the bar from the fire to the hand, and enters the hand. In the same way the heat of the land and the water passes into the air that touches them, and is conducted farther and farther away into the air, warming it on the way. Again, this heated air is lighter than cold air, and rises, while the cold air flows in and takes its place, or, rather, forces it to rise, carrying the heat upward into the atmosphere. So the atmosphere is heated in three ways—1 by absorbing the sun's rays, by 2 abstracting the heat from the land and sea, and by the rising of the heated air into higher regions.

But while the ground absorbs heat very readily, it is a very poor conductor of heat; indeed, the heat does not go down more than five or six feet, so that under the action of the sun's rays the top of the ground would get very hot were not the heat parted with just as rapidly as it is absorbed. But the air does not do so; hence at night time, when the sun is away, the ground is cooler than the air, and hence dew or frost may form on the ground when there is none a few feet above it. Hence, too, during the long days and higher sun of summer the heat accumulates in the air, while in winter the long nights allow more heat to pass away than the short days with their low sun can make good, and so the cold continually increases.

The sea, unlike the land, absorbs the sun's rays slowly, but it is an excellent conductor, so that the water is affected by the heat 600 or 900 feet down, and as it gives out its heat slowly too, the temperature of the air over it is nearly always the same as that of the sea itself; and as the upper part of the sea moves steadily from the heated equatorial

regions toward the colder regions north and south, the sea thus becomes a vast heating apparatus for the regions that lack; it heats the air over it, which is carried far across the neighboring land.

If there were no atmosphere, the objects that absorbed the sun's rays would become hot, but would almost instantly become intensely cold when the sun disappeared; objects in the shade would have no heat, and while one side of a body would be very hot, the other would be freezing. Life would be impossible. There is an approach to this state of things in elevated situations in dry climates; in the open sunshine the heat is often very great, while at night the cold is intense.

44 **HEIGHT OF THE ATMOSPHERE.** It is not known how far the atmosphere extends above the earth, but it is known that air becomes thinner and thinner as the distance above the ground increases, till at a height of no more than six miles breathing is impossible and birds cannot sustain themselves on wing. The vapors of the atmosphere reflect light; if they did not there would be light only while the sun is above the horizon: our twilights are caused by reflected light, but the light comes from no greater distance away than fifty miles; higher than this the air is so thin that it cannot even reflect light. Yet the atmosphere must extend beyond that; for meteors, which are so numerous and splendid on clear nights of mid-autumn, are small masses of dark matter in immense swarms wandering about in the solar system at a fearful speed. They are not visible even through a telescope, and make their presence known only when they suddenly flash out as streams of light, the "head" being the most brilliant. It has been shown that meteors become glowing hot by their friction with the earth's atmosphere, into which they plunge. Some of these meteors are known to have been at least two hundred miles above the earth when they burst into flame. The atmosphere must therefore be that many miles deep, but it must be also very thin.

46 **WEIGHT OF ATMOSPHERE: THE BAROMETER.** As the earth attracts everything to it, including the atmosphere, and as it is attraction that gives weight, therefore the atmosphere must have weight, or must press upon the earth; then, too, the weight, or pressure, must grow less according as the distance above the earth increases, for the force of the attraction is less, and there is less air to be attracted. But although we might infer these facts from our knowledge of attraction, yet we could not infer what would be the weight of a column of air extending the whole height of the atmosphere.

This last fact, and many others, have been revealed to us by that simple and well-known instrument, the Barometer*—the "measure of

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*The barometer is of too common use in our schools to need description.

weight." A column of air whose base is an inch square, weighs about *fifteen pounds* (14.74 lbs.). At a distance of about three miles and a half above sea-level the column of mercury in the barometer tube is only fifteen inches long: half of the atmosphere is thus seen to be below the height of three miles and a half.

HIGH AND LOW PRESSURE. At sea-level, with the thermometer at 32° F., the column of mercury in the barometer tube stands at about thirty inches; above sea-level it will not stand so high, for the pressure on the mercury will not be so great, as there is less air above it.

But at sea-level itself, as well as elsewhere, the column of mercury sometimes stands higher than thirty inches and sometimes lower; if at thirty inches or more, the pressure is said to be *high*; if at less than thirty, *low*.* This difference must be caused by changes in the weight of the air above.

It is well known that the slightest increase in heat in any place will set the air in motion both away from and toward such place. Boys know how, even on a calm night, the smoke and sparks of a bonfire will rush upward, twisting and whirling as they go, and how wind will come in little gusts along the ground, puffing the smoke and sparks in the faces of those gathered near. The fire heats the near-lying air and makes it expand and so become lighter, while the cooler and heavier air farther away moves rapidly toward it along the ground and forces it to rise. Now, as the heat creates an upward movement of the air, the air in this ascending current cannot press so heavily on the mercury of the barometer as when there is no such upward movement.

Then, again, as can be proved in any school laboratory, moist air is not so heavy as dry, and the more aqueous vapor there is in it the less it weighs; so when the air has a great deal of moisture in it, the barometer is low, and when there is but little the barometer is high. The height of the barometer varies, therefore, according to the heat and according to the moisture in the air. But there

* When noting the pressure in elevated positions allowance must be made for the height above sea-level; and so in such places the pressure may be high although the mercury is at far less than thirty inches. In reports, the actual pressure on the barometer is always "corrected for sea-level."

are modifying conditions to this. As aqueous vapor is always present in large quantity in all our storms, we can readily see of what great value a barometer is, especially to seafaring people. A falling barometer foretells an approaching storm, and "forewarned is forearmed."

46 **WEATHER FORECASTS, ISOBARS, ETC.** As so much that concerns our well-being depends upon the atmosphere, all civilized nations have for many years past been carefully noting and recording, over wide areas, the daily and hourly variations of the barometer, the changes of temperature, the movements and force of winds, the storms, rain or snow, etc. A vast deal of knowledge has thus been gained about the atmosphere, and much of it scientific men have been able to use for the public benefit. Our weather forecasts, or "probabilities," are of great value, especially to farmers and sailors, notwithstanding some failures; yet much concerning the air remains to be learned, possibly never can be learned.

"Weather Maps" are issued by observatories, indicating the weather conditions prevailing at a given time over wide areas—with us, from the Pacific to the Atlantic, and from the Gulf of Mexico as far north as the telegraph extends, for without the telegraph such maps would be impossible. On these maps lines, often of a curiously intricate course, called *Isobaric* ("equal pressure") lines, connect all places where the pressure is the same, and thus show where storms are existing, threatening or passing away, and where fine weather prevails. From the records of high and low pressure, maps are also constructed showing the average, or general, pressure during any extended period of time over any given area—Canada, United States, Great Britain, Europe, etc. See Figs. 145-7:

MOVEMENTS OF THE AIR: WINDS.

47 The atmosphere, we have seen, is a part of the earth—its outside part—enclosing land and sea, and attracts and is attracted in the same way as land and sea. It is a fluid, as water is, and is even more sensitive than water to any differences in pressure in its mass—any differences in temperature, in density, in height, or in anything that tends to disturb its equilibrium, or perfect balance of all it parts. If the equilibrium is disturbed, if any inequality anywhere appears, movement takes place in order to restore equality.

Now, heat, or rather the very unequal way in which heat is distributed through the air, is the great disturber of the atmosphere's repose. Were the atmosphere every-

where heated alike, from bottom to top and from the equator to the poles, all would be at rest, the air would be everywhere in equilibrium.* But everywhere the conditions that cause inequality are multitudinous, and so the air is never at rest; and it is fortunate for Life that such is the case: no Life could exist in a motionless, a dead atmosphere. The purity and life-sustaining power of the air depend on its continued movement as well as the purity of the ocean depends on its movement.

We know what effect heat has on the air—how it makes the air in the heated space expand, become thinner and lighter, and how the cooler and in consequence denser and heavier air round about, in obedience to the law that governs all fluids, will flow into and beneath this lighter air and force it to rise. And this moving of the air is *Wind.*

It is not possible for the air to be at rest: in the hottest and stillest days of summer little puffs of wind will darken the water, rustle the leaves or fan our face, and each has its cause in unequal heating. The air on hill-sides is cooler by night than that in the valleys, and so a current flows downhill, while by day a current, often among mountains as a strong wind, flows upward; by day the sea, the lake, the river are cooler than the land, and then a breeze blows from them to the shore, while by night they are the warmer and a breeze blows towards them; a southern slope warms the air to a greater degree than a northern slope; clouds cover the sky over one region shutting out the sun's rays, while a neighboring region lies in brilliant sunshine; in one part of the earth the sun never rises high in the heavens, in another the scorching heat from directly overhead pours down for weeks and months together; a clayey soil is cool, retaining moisture for a long time, while a sandy soil throws off its moisture rapidly and becomes hot;—desert countries whether on plateaus or in valleys, in temperate regions or in torrid, glow like furnaces with blinding light and heat beneath the midday sun, and are bitterly cold when the sun is gone.

But while these are all causes of unrest they are for the most part causes also of irregularity in the movements of the air, of a complexity that almost seems to be capricious: the land surface varies endlessly in form, in height, in exposure, in slope, in composition; the land may be barren and bare or covered with vegetation, the sea may be near or far off, and the latitudes may be high or low or middle. And thus local causes for the endless variations in the direction of winds everywhere exist too.

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*The unequal distribution of aqueous and other vapors also affects the equilibrium of the air, but this may be passed over here.

CALMS, DOLDRUMS, HORSE LATITUDES. Yet regions of constant, or almost constant, calm are known to exist, but for the most part, as might be expected, in the ocean away from the land, for, as we have seen, the sea is not apt to part with its heat readily, or to become heated readily.

In the equatorial regions there is a wide belt of sea known as the *Doldrums*; in the Atlantic it is always north of the equator, extending up to or beyond 10° N. in our summer, but not so far in the winter; in the Pacific it does not extend quite so far north in summer but drops south of the equator two or three degrees in winter. It is a sultry region with only occasional little puffs of wind; it has a cloudy sky whence, especially in the afternoon, torrents of rain accompanied with thunder and lightning fall with little or no warning; it has a low barometer, and it is the gathering place of the terrible hurricanes.

In the neighborhood of the tropics north and south, is a narrow belt of light variable winds, and calms, but with nothing of the dead sultry weather of the doldrums; the air is fresh and clear and the barometer high. These belts are the *Horse Latitudes*.

TRADE WINDS: RETURN TRADES. Then there are some winds which blow constantly in the same direction, and others which, though not constant, blow prevailingly in the same direction. Of these the first are the well known *Trade Winds*, so favorable for sailing-vessels. They blow from about the tropics towards the equator, and die away at or near the doldrums; in our northern hemisphere they blow from the north-east, in the southern hemisphere from the south-east. These winds are usually fresh and strong, and vessels may go on for days without altering their sails. The sky in the "Trades" has some light clouds during the day, but is usually clear at night; the temperature is warm and the barometer high; storms seldom occur except when the hurricanes from the doldrums pass through. They are dry winds when they first appear at the tropics but rapidly gather moisture as they move onward, till where they die away, they are almost at the point of saturation. The sea beneath them is salter

than elsewhere. Where they cross islands with high mountains, as in the West Indies, they seem to have a depth of about two miles, for on summits higher than two miles the winds have a general eastwardly course.

On land they are practically destroyed, for mountain ranges and the varied conditions of the land change their direction and otherwise interfere with them, while the inequality of the heating, especially in the different seasons, wholly removes them.

Besides these Trade Winds there are the *Return Trade Winds* (or Anti-Trades). They are winds in the regions outside of the tropics extending as far as lat. 50° N. and S., and in the north-eastern Atlantic and Pacific far beyond that; they blow for the most part just in the opposite direction to the Trades; they are the warm south-west winds that often visit us here in the middle of the continent, and are the common, though not constant, winds of summer and winter in the northern Atlantic and Pacific; and as warm, strong north-west winds they bring heat and abundant rain to south-western South America.

Beside all this, it is well known, even though the weather reports did not tell us so, that winds coming from some westerly direction are by far more common throughout the year than those coming from any other direction. What is the cause of these calms and these constant winds in the midst of so much that brings unrest and variableness?

THEORY OF THE WINDS. As has been already said, the barometer shows that the region of the equatorial calms, including the doldrums, is one of low pressure; it is a region also of continuous heat. The heat causes the air to expand and thus to become lighter, whereupon the cooler and heavier air from the surrounding regions north and south flows in below and forces the lighter, warmer and moisture-laden air to rise. This upward flow of air is uninterrupted, and so in the upper regions of the atmosphere the air must tend to rise higher than the general height of the air elsewhere. But fluids will not thus pile up and stay so, they will flow off, and so the air that has been, and is being, forced up, continually flows off toward where the level is not so high, as it were, or "down the gradient" toward the polar regions.

It is the upward flow of the air that causes the calms of the doldrums and that gives the low barometer, while it is the cooling and condensing of the warm, light, moisture-laden air that gives the cloudy sky, the torrencs of rain, and the sudden thunder storms of the same region.

In the upper regions to which it is forced, the heated air becomes cool, and as it flows off poleward it settles down continually in all latitudes towards the earth, the lower portions of the moving mass drifting off and forming a return current, just as we have seen water do where an eddy exists;—the return current is only an eddy of the atmosphere moving contrary to the general flow. The upper part of the poleward current flows on its course: of the lower part some returns to the equatorial area as the Trade Winds, but some starting near the tropics flows poleward, as does the upper current, along the surface of the earth as the Return Trades—a south-west wind in our hemisphere, a north-west wind in the southern. This latter and the top current finally join in the high latitudes in the great return current.

Thus there are three currents, the upper passing on to the poles, the lower along the surface of the earth also passing on to the poles, and the return current between these two, and formed by them, flowing equatorward.

But all this does not account for the known directions that the great surface currents take, and for what is known of the direction of the return current.

It has been mathematically proved that a body moving in any direction whatever on the earth, or on any other revolving sphere, tends in the northern hemisphere to turn to the right of the direction in which it is moving*, and to the left of it in the southern hemisphere. The overflow currents of the upper atmosphere therefore continually turn, or are deflected, as they advance poleward, and so move spirally eastward, and with increasing speed.† In the polar regions, at least high up in the atmosphere, the motion must be almost wholly eastward, the poleward movement having become lost; but in the lower atmosphere the friction against the earth is so great that the poleward movement is not lost, but the air moves on in a spiral course as a westerly wind, south-west in our hemisphere, north-west in the other.

Between the upper current and the lower, the return current, supplied by both of these, passes on toward the equatorial regions with a spiral motion also, and still moving eastwardly as a result of its former advance poleward; till when the tropics are reached, the curving tendency over-masters the eastward movement and the whole current passes on in both hemispheres as Trade Winds. In the doldrums it ascends to begin the circuit anew.

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*A revolving disk is among the apparatus of every school. Cover the disk with a sheet of paper; the outer rim is the equator, the centre is one of the poles, from which meridianal lines run to the equator. While the disk is turning from right to left, with a pencil try to draw a straight line on the paper in any direction. The line made will be found curved as stated.

†This is in accordance with the law of bodies revolving round a fixed point, the radius continually decreasing. It is illustrated by the action of a stone tied to a string and whirled round with the hand. If the string be allowed to wind up round the finger, the stone will whirl faster and faster as the string shortens. The stone and string must "pass over equal areas in equal times," the shortness of the radius being compensated for by the greater rapidity of the movement. (See page 387.)

Where the air settles down from above to form the Trades and the Return Trades, at the place where, so to speak, it hesitates which way to go, north or south, there are calms,—the Horse Latitudes; here there are no gradients, no slopes, to the layers of air.

It is said on a preceding page that the prevailing winds of the world beyond the latitude of 30° north and south are known from observation to be westerly,—south-west, west, north-west. The theory given above fully accounts for this fact. In the southern hemisphere, where the land surface is small, so constant and so strong are these winds that sailors speak of them as the "roaring forties," and the long heavy seas of those southern latitudes and the great difficulty experienced by sailing-vessels in rounding Cape Horn westward, are the result of these heavy winds.

Fig. 144. The winds of the earth. Outer circle, the overflow to the poles; inner circle, the return current with Trades and Return Trades. Inner disk shows westerlies, Trades and Return Trades, and belts of calms at equator, tropics and poles.

It is found that, as the higher latitudes are approached, the barometer slowly falls, and therefore, though little is really known, it is supposed that an area of low pressure lies over the polar regions, not very marked in the north, however, where the isobar of 29.90 passes over the pole, but very marked in the south where the isobar of 28.00 is thought by some to cross the pole. These low-pressure areas, where a calm may possibly prevail also, are a result, too, of the deflected movement of bodies on a revolving sphere. The eastward movement becomes so decided and so rapid that if all causes of friction were absent, there would undoubtedly be a vacuum over the poles and the barometer would stand at zero. But the enormous friction to which the air is subject prevents this; still, the centrifugal force around the poles, especially around the south pole, is strong enough to diminish the pressure appreciably, and create an area of low pressure where all other conditions lead us to look for an area of very high pressure.

It must be remembered that when the overflowing equatorial air starts poleward, it has an eastward motion of 1000 miles an hour; at lat. 60°, if there were no friction or other hindrances, it would be mov-

ing 2000 miles an hour; at forty miles from the poles, 100,000, and then there would be a vacuum. The fearfully rapid motion of this huge "revolving cap of air" would force all the air away from the centre,—the poles would have no air over them. How fast it actually does move in the upper regions we cannot tell. Clouds move at times over 100 miles an hour; but clouds, even the highest, are not far away, and mountains do not pierce far enough, nor can balloons rise high enough, to afford opportunity of gaining information. Cf. "Tropical Cyclones," page 304.

PERIODICAL WINDS: MONSOONS. It will be seen from the foregoing that where the heat changes from season to season, the winds will change their direction more or less with it, and thus tend to become of a periodical character. And should there be a land surface of great extent, it will, during summer, through the greater number of hours in which it is exposed to the sunshine and the greater elevation of the sun, become very much warmer than usual, and thus will be a vast area of low pressure to which the air will flow from all sides; while in winter through the reverse conditions the pressure will be unusually high and air will flow out toward all sides. In both cases the winds will continue constant for a long period.

Though this condition of things is found in many places, in North and South America, South Africa, Australia and others, yet central Asia offers the most striking example of it. The pressure in summer north of the Hymalaya mountains is quite low for nearly six months, and then there is an inflow of cooler air from the ocean at the south,—the southerly *monsoons* as they are called,—whose load of vapor falls as rain over so much of India; while in winter when the high pressure prevails to the north, cool dry winds—the northerly *monsoons*—flow down over India for nearly six months, bringing the dry season to most places; but becoming moisture-laden in crossing the Bay of Bengal, they bring rain to south-east India, which gets little from the south-westerly monsoons.

LAND AND SEA BREEZES. These are precisely of the same nature as monsoons; with us they occur only in the fine weather of summer, and then the sea breeze cannot go far inland, not more than twenty miles or so, nor the land breeze reach far out to sea; but within the tropics they occur all the year round.

In mountainous regions in summer strong winds often blow up the valleys during the day followed by a calm in the evening, after which

cool winds set in and blow down the valley all night till the morning, when there is another calm. All this is only the heated air of the day-time flowing up the mountain in natural channels, as it were, then after a pause when the ground has lost its heat, the cool heavy air of the higher regions flowing down the same natural channels. The last is a state of things that in the case of enclosed valleys may result in frost or a great degree of cold, while the hillsides are much warmer.

CYCLONES. We have all seen a little whirl of dust and straws and bits of paper suddenly start up before us and hurry away along the street or over the fields, the various fragments that have been gathered up at the bottom flying out at the top in all directions as the whirl sped on its way. This is a *Cyclone in miniature*, "the revolving or circular storm," the same in action and the same in cause as the terrible cyclones of the tropical regions, the needful cyclonic storms that bring rain or snow of temperate latitudes, and the wild tornadoes that create such destruction in their fearful but happily narrow path.

TROPICAL CYCLONES: HURRICANES. In the months of August, September and October within the doldrums—those regions of hot moisture-laden air and almost dead calms—when in our hemisphere they are farthest north, there often spring up far out in the ocean, no one knows precisely how, whirls of wind that grow larger and larger till they may reach a diameter of over three hundred miles, and that move forward often at the rate of fifteen miles an hour. The wind, gentle at first and coming from all quarters, blows spirally inward toward a centre, growing stronger and stronger under a sky of ever-increasing gloom, till it at last attains an awful force and rapidity, the dense low-hanging clouds reaching up five miles into the air and pouring down torrents of rain amid deafening peals of thunder and the roar of a mad sea. But the centre, the "eye of the storm," is a dead calm with a hot dry air and a very low barometer, the sea in fearful commotion, while the clouds overhead break away and the clear sky is visible,—but not long. For with a moaning sound and then a prolonged roar the tempest breaks again with all its former fury:—the storm has moved onward, and the centre, often thirty miles in diameter, with it. But now the wind comes from a quarter opposite to that in front of the storm, and after raging for a while, slowly loses its force till in two or three days again the whole ocean is as calm as if no tempest had passed over it. Many a thrilling tale of the sea has made us all acquainted with these terrible *hurricanes* of the West Indies and the equally terrible *typhoons* of the East Indies.

In our hemisphere the winds in this whirl blow contrary to the movement of the hands of a watch, and the whirl moves somewhat north-westwardly to about latitude 25° where it turns rather abruptly to the northeast; in the

southern hemisphere the motion of the winds is with the hands of a watch, and the whirl moves somewhat south-westwardly and then turns south-eastwardly, losing gradually its force till it passes into an ordinary storm, as is the case in the northern hemisphere also.

The cyclone makes known its approach by a somewhat higher barometer than usual, by low swells that have

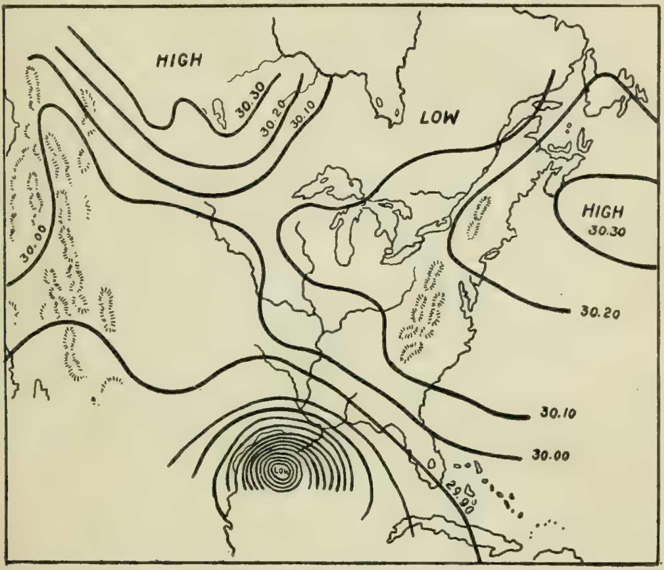

Fig. 145.—Hurricane just nearing Galveston Sept. 8, 1900. Note very high pressure to north and north-east. Isobaric lines for every tenth of an inch of fall of barometer; depression at and near centre not known.—Courtesy of R. F. Stupart, Director of Meteorological Service for Canada.

outsped it, followed by light clouds and increasing wind, a slowly sinking barometer and a threatening evening sky. A skillful captain noting these signs will not allow his vessel to run before the wind, for it will certainly carry him into the very centre of the storm. If he is south of lat. 25° and the wind is from the north, or north of lat. 30° and the wind is from the south, he will know that the cyclone is advancing dead upon him and will steer away, if possible, from its fearful track. (See figure 147.)

These cyclones do not form on land or near land, but far out at sea; if in their course they encounter the land, especially if high, they are soon broken up, though the coast exposed to them may suffer fearfully, as the West India Islands and the southern United States know to their sorrow. The doldrums, owing to the great heat and moisture of the air, among other things, are subject to sudden and violent changes, as the sudden thunder storms show. Hence many scientific men think that, as cyclones are formed nowhere else, a large area of the doldrums becomes unusually heated, and as the air in consequence expands and rises, the air around flows in to be heated and to rise in turn, and thus a movement towards a centre is given to the still air which becomes ever wider and wider. The circular motion is first started by the rotary movement of the earth and gradually increases in rapidity, —just as is seen in a basin from which the water is being drawn from an opening at the bottom; the water if a little circular motion is in some way given to it, will revolve more and more rapidly as the outlet is approached. And *there will be a hole in the water above the outlet*, just as there is no wind in the centre of the cyclone while the mad tempest is roaring in a circle around it. The torrents of rain and the density and depth of the clouds are the result of the fierce uprush of air to cooler regions, and of its furious whirling, both condensing the vapor in it.

The cyclones occur in all the large tropical bodies of water:—in mid and western Atlantic, in the China seas, where they are called *typhoons*, in the Bay of Bengal, where they occur in early summer and in the fall, in the Arabian Sea, the Indian Ocean and the South Pacific,— but *not the South Atlantic*,—for here the doldrums do not come south of the equator, and it is supposed that though there are overheated areas of ocean here, yet the inflowing winds, on account of being so near the equator do not have the whirling motion given to them.

Figs. 145, 146, 147 represent the great hurricane that on Sept. 8, 1900, laid Galveston, Texas, in ruins. It was first observed east of Martinique, Aug. 30; next day it was north of Antigua, the barometer being at 29.84. The winds in the West Indies were only light, but the rain was heavy. By Sept. 6, the hurricane was near Florida, and strong gales with a low and falling barometer were being reported from the

north of lat. 20°. It was at Galveston with its work of ruin on the 8th, doing almost as much damage to places some miles inland; but it rapidly lessened in violence as it turned almost abruptly to the north-east, passing into Canada down the lakes and the St. Lawrence, giving a wind of from 44 to 48 miles an hour at St. John. Fortunately it did comparatively little damage to life or property in its violent course except in Newfoundland, where many lives were lost and great quantities of fish were destroyed.

The following is the note on the weather map at Toronto, Sept. 12, 1900:—

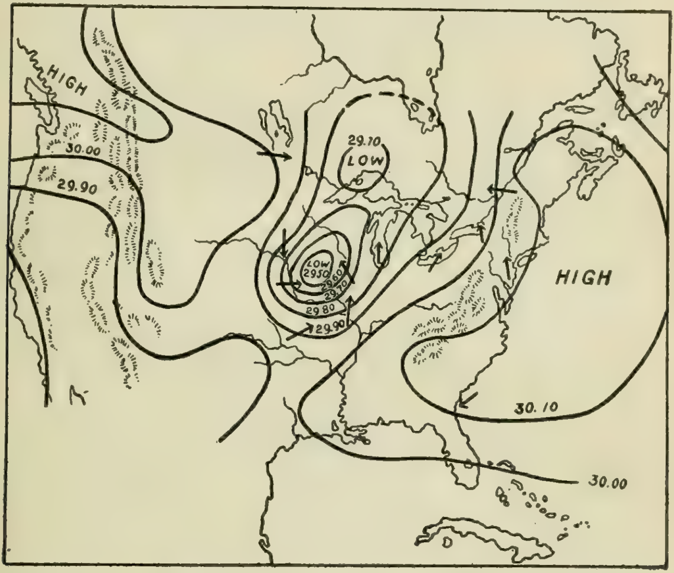

Fig. 146.—The hurricane, now only a somewhat moderate cyclone as shown by isobars, approaching the Lakes from Iowa. Arrows show direction of winds. Note the secondary "Low" area. —Courtesy of R. F. Stupart.

"The disturbance which was situated in Iowa yesterday morning has since developed great energy and it is now centered near Montreal as a very severe storm. This storm is no doubt a secondary development of the West India hurricane that swept over Texas on Saturday last. A very heavy gale set in over the Lake region during the night and heavy gales are indicated throughout eastern Canada."

Galveston is situated on a low island, one of the string of sand-islands that border the Texas coast, and the destruction caused by the waves was far greater than that by the winds. For in these hurricanes the very low pressure in the centre of the terrific whirl must cause the

water to rise there; so that on the coast destruction is caused not only by the waves that are raised and driven forward on shore by the wind, but also by the uprising of the sea bodily, as it were, upon the land in consequence of the greatly lowered pressure.

CYCLONES IN TEMPERATE ZONES.

We, too, in the Temperate Zones have cyclones; they have the same movements of the wind,—a spiral flow inward toward the centre and upward, and the same motion of the whole whirl, north-eastwardly as a rule in the northern hemisphere, south-eastwardly in the southern, the winds of the whirl moving in the former against the hands of a watch, in the latter with them. But there are many differences; ours cover a much larger area, often a thousand or more miles in diameter, they do not extend high into the air, the winds though sometimes doing damage, are never so terribly fierce as in the others, the barometer never stands so low in the centre, nor is this centre calm; they are far more frequent and severe in winter than in summer; the winds of the tropical cyclones are all hot and moist, those of our cyclones are warm and moist on the south and east of the cyclone, but cold and dry elsewhere especially in the west; our cyclones are oval in shape, not nearly circular as the others are, and they move forward two or three times as fast.

As our cyclones occur most frequently in winter when there is little heat in the atmosphere, it is thought they cannot be due to the expansion and consequently the rising of air by reason of heat; their cause is even less known than that of tropical cyclones. But whatever their cause they bring us our storms of rain and snow, and so do far more good than the occasional violence of their winds or the severity of their cold can do harm.

We naturally expect that, if a storm-wind comes to us from the east, the places eastward of us get the storm first. This is true of short distances only; for a study of the whirl in Fig. 47 will show that while Montreal is getting a fierce east wind, Quebec is getting a south-east one, and places farther east still, a south wind. So a person by noting the direction in which a storm wind is blowing, may readily tell where the centre of the storm is.

Cyclones do not invariably move in a north-eastwardly direction with us, as the following note from Toronto Observatory shows (Monday, June 15, 1903):—"The storm of the last few days was a most peculiar one, and to get an analogy to it we must go back nine years.

About four days ago the storm was centered off the New England coast; Friday night it moved to the Ottawa Valley; Saturday it was south of Georgian Bay; yesterday it moved south-west toward Detroit and Lake Erie, and last night and this morning it travelled back east again, to the starting point in the New England States. The circle is complete."

ANTICYCLONES. Very strangely there follows these cyclones, and to the west of them, a cyclone of quite a different character—just the reverse of the other. Instead of getting lower and lower, the pressure gradually rises as the centre comes nearer; the winds, which are

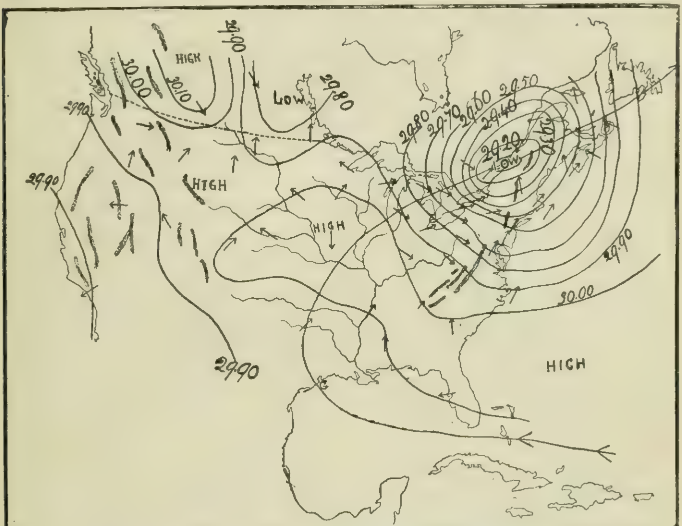

Fig. 147.—The hurricane, now a furious cyclonic storm, centered on Montreal. The line running between Cuba and Florida marks the path of the hurricane, shown by arrow-heads; G is Galveston; numbered lines are isobars; the arrows mark the direction of the winds. Note that the arrows point outward from the "High" or anticyclone areas, and run parallel to the isobars or across them to the "Low" centre.
—Courtesy of R. F. Stupart.

always gentle, flow outward from the centre, which is often wholly calm, so that it is thought the air forming its winds must settle slowly down from the upper regions, bringing a grateful coolness in summer after a storm and often intense cold in winter. This is the *Anti-Cyclone*, the bringer of fair weather, and weather maps which show

us the region over which a cyclone has travelled, and in various ways indicate the severity of the storm, also show us the anti-cyclone following close after. (See spaces marked *High* in Fig. 47).

LOCAL CYCLONIC WINDS. We have seen that our cyclones are often of great extent, and so the wind of the different sides may come from very different regions. In Canada, in summer, no very great difference exists in the character of the winds during a cyclone and after it has passed, except in their violence. But it is otherwise in winter: then the winds on the right hand front may come from the warm region of Florida or the Gulf of Mexico, bringing a thaw and often rain, while in the rear are the bitter winds from west and north. Or the whirl may pass over the eastern Pacific; the winds will then be warm and moist, and striking the western mountains will leave much of their moisture on the western sides as snow or rain, and pass on thin and cool to fall, and to condense and thus become warmer as they fall upon the plains at the other side of the mountains—as dry, warm winds that "devour the snow," the *Chinook*, of western America.

Similar is the *Fœhn* of the Alps. The indraft of the cyclone passing to the north brings down the wind from the mountains where it is cold and dry, getting drier and warm in its descent, till at last the air may be drawn even from Italy where it is moist and warm; then rain and snow fall on the southern side of the Alps, and clouds stream out from their tops but do not come down to the northern side, for the dry lower air re-absorbs any moisture that the high cold air cannot contain.

And if the southern whirls pass over the hot, dry Sahara desert, they bring the hot, dusty, parching wind—the *Sirocco*—to Spain, Sicily, Italy, or even France, though after crossing the broadest part of the Mediterranean and the Adriatic and becoming moist, they may lose their moisture on the Alps and fall raw and cold upon S. E. France in the *Mistral*:—Just as the "*Norther*" sweeps down from the mountains upon Texas, the *Pampero* upon the plains of Argentina, and many another wind of similar origin in other parts of the world.

Excessively hot winds in various countries are thought to be of cyclonic origin, but intensified in some way not yet determined. Such are the *hot winds* of Texas and Kansas, the *Khamsin* of Egypt, the *Harmattan* of the west coast of the Sahara.

THUNDERSTORMS. We all know the thunderstorm:—Low down at some point of the western sky in the afternoon or evening, usually, of a hot day—though not at all unknown at other times and seasons—we see rugged piles of clouds rolling up, or the sky darkening down, till we become aware of a haze or of light, thin clouds

that shut off the blue over our heads; then we see faint flashes of lightning play over the clouds which in the meantime have become denser and darker and stretched out across the heavens; soon the thunder is heard and as it comes nearer we see the base of the cloud, now heavy and threatening, extend in an even flat line to right and left, below which all is of a dull white color—the rain sweeping along over the country, shutting out from sight everything behind it. But now the wind, which has been hot and sultry and blowing toward the advancing cloud, drops and there is an ominous uneasy stillness in the air—to be broken by a louder crash of thunder, accompanied by a rush, often of destructive strength, of cooler wind from under the cloud;—it is the *thunder-squall* that has sent the inexperienced occupants of so many boats to a watery grave. The storm has come with flash of lightning, roar of thunder, the outpour of rain, and the rush of wind. But it is soon past, for it moves rapidly eastward, sometimes as fast as fifty miles an hour, and finally dies away, its force being spent.

We do not yet know much about the causes of thunderstorms. They seldom occur except in the warm season, never either in summer or winter without being preceded by an unusually warm spell. There is an upward and inward movement of the air, for we can see the little clouds drifting into the big one, and we can see, too, the clouds rolling upward,—growing from the top till at last they spread out, drifting along in the upper westerly currents of the air. They seem to belong to our cyclonic storms, for they usually occur a little to the east of south of the cyclonic centre, and from 300 to 500 miles away from it, where the cooler westerly winds reach a region of heated wind.

The rain comes from the condensation of the water-vapor in the air, and is thought to start as ice-crystals in the top of the dense deep cloud, where the upward motion of the air ceases, and then in falling through the cloudy matter below to attract other water particles till large drops result. The wind, too, aids this uniting process; if it is violent the drops may be driven upward through the cold air again and again until large drops of ice are formed that can no longer be supported, and when they reach the ground we call them *hail*.

The discharges of the electricity—or the flashes of lightning—arise, it is thought, from the union of many rain particles into one, the electricity with which each particle is covered accumulating in one body, as in an electrical machine, until it is overcharged, and then the "*spark*" or succession of sparks that we call lightning, passes from the

highly charged cloud to the less highly charged, though much must come to the earth, and much remain diffused in the air.

The *Cloud Burst*, so common in the south-western United States, and creating such destructive floods along streams, is a thunderstorm in which a large mass of warm moist air is very suddenly cooled and condensed, and the moisture thus suddenly set free falls in a body to the ground. Some think that a great body of rain is held up in the air by very strong upward currents, and when these cease the rain falls in a mass.

TORNADOES. These fearful storms, often, but wrongly, called cyclones, are, as it were, a storm within a storm; for they belong to a thunder storm, moving with it for perhaps twenty miles or so, but along a narrow path varying from a few rods to a quarter of a mile or so in width. The wind, warm and moisture-laden, whirls spirally and with fearful violence round a central area a few yards in diameter, which is thought to be calm and of very low pressure. The warm, moist air cools in its upward rush, forming dense clouds, from which torrents of rain fall, while the clouds seem to stretch in a long funnel-shape downward to the ground;—it is the increasing violence of the whirl expanding the air and making it less capable of containing moisture, which therefore becomes visible as cloud. This is the most violent stage of the tornado and the ruin that marks its path is often appalling. Nothing can resist it: houses are overthrown, trees torn up and carried high in air miles from where they stood, crops destroyed, cars and engines lifted from the track—in short, universal ruin attends it. (Cf. Tropical Cyclones, page 304.)

Tornadoes are far more frequent in the Mississippi valley than elsewhere: they occur usually in the warm afternoons of heated periods in summer, and even in winter during a warm spell. They move in an eastwardly or north-eastwardly direction, sometimes south-eastwardly, at a rate varying from twenty to forty miles an hour, and last from half an hour to over an hour. We know them to some extent in Canada; one occurred in the Township of Mornington, Ontario, in May, 1903; but ours, though destructive enough, do not reach the violence of those in the Mississippi valley.

Water Spouts are scarcely more than tornadoes passing over expanses of water, but they are not attended usually by thunder and lightning: nor do they suck up water from beneath them, for the water with which vessels caught in them are deluged, comes from the condensed moisture of the air and is fresh, not salt. Little is accurately known of them or of tornadoes either.

RAINFALL, TEMPERATURE, CLIMATE.

The requisites for rain have already been referred to,—aqueous vapor in the air and some conditions that will cause it to condense and fall to the earth. The vapor, directly or indirectly, comes from the sea, while the winds carry it everywhere, so that every part of the earth, both land and sea, receives either rain or snow, or both, unless the conditions are such that condensation cannot take place.

RAINFALL OF EQUATORIAL REGIONS.

In the equatorial belt of almost uninterrupted calm, the condensation takes place, as has been said, through the rising of the expanded and vapor-laden air into the higher regions of the atmosphere, where it loses much of its heat, or is cooled beyond the point of saturation, and so cannot contain all its vapor. Rain is therefore the result. This is the region of the most abundant rain; for, with its greater heat, it contains far more of the ocean-surface than any other region, and its gentle surface winds carry little of the vapor to other regions; the weak easterly current of air that blows along the equator counter to the prevailing westerlies, does not carry the moisture away to the side regions, but in South America at least, carries it over the equatorial land producing the very abundant rainfall and the wonderfully luxuriant and varied vegetation of the Amazon basin.

But here, as elsewhere, other conditions bear upon the amount of rainfall any one place or district receives. Across the path of the easterly counter air-flow of the Amazon basin the Andes mountains lift themselves; these force the warm, moist air to rise quickly in a body to the cooler heights above, with the result of a heavier rainfall here than in the valley to the east. But the excess that the eastern slope of the Andes gets, is at the expense of the western slope, for western Peru and all the western equatorial coast are dry, much of it being desert; only at intervals, sometimes of many years, is there a heavy rainfall.

In India, Bombay lies on the west coast, Madras farther south on the east coast, and Colombo some 400 miles farther south still, in Ceylon;—

The following is the report of the rainfall in inches in these cities for four months in 1902:—

	Aug.	Sept.	Oct.	Nov.
Bombay......	16.53	27.11	.78	.01
Madras........	3.26	4.65	20.69	10.51
Colombo.......	2.76	8.18	16.85	20.10

In the first two months Bombay gets a heavy rainfall, and almost none in the following two; while the two other cities get a moderate fall for the first two months and a heavy one for the following two. The months of August and September are the last of the south-west monsoon months (page 303); and as the western Ghats, those "step-like" mountains that border the southern half of the Indian peninsula, rise across the path of the monsoons, they too, like the Andes, force the moisture-bearing winds into higher and cooler regions, and so Bombay and the west coast generally, get an abundant rain; but the plateau country beyond gets comparatively little, for it has no higher ground that will force the winds still farther up, and wring more moisture from them. But when the monsoons turn in the autumn and blow from the north-east, then, though they bring only a little rain to the rest of India, even in the higher elevations, they bring a heavy fall to Madras, Colombo and the south-east, while Bombay and the west go dry. For when in the late season they fall cool and dry from the high interior, they pass over the Bay of Bengal and there become warm and full of moisture, and so when they reach south-eastern India with its eastern Ghats, they give a plentiful downpour of the needed rain. In this southern region of India, though the central part is dry, there is no desert land as in western Peru, for the Ghats are not as high as the Andes, and therefore the winds still keep some moisture for the low-lying districts beyond

But there is a partial desert elsewhere in India, to the east of the mouth of the Indus, where the country is much like the steppes of eastern Russia, with a vegetation during the

south-west monsoons but parched and sandy at other times. For the monsoons are light here, and the rain is very scanty; the great mountain-mass of the Sulimans lies to the west, and across these, at least their southern and lowest portion, the monsoons must go to reach India. Directly north of this in the northern Punjaub, where it would seem the south-west monsoons could not reach to give rain on the low ground, there is an abundant but not heavy rainfall. For the monsoons after sweeping over southern India and up and across the Bay of Bengal, are turned from their course by the great curving mountain-barrier of Assam and the eastern Himalayas, and pass up the valley of the Ganges, as south-east winds, to the very north of the Punjaub itself.

A like deflection of these winds is caused by the Vindhya Hills of central India, along whose southern base and side, where the winds are forced to the east, the rain is abundant, but scanty on the northern side toward the west; here, however, there is some compensation, for the winter monsoons have gathered some warmth and moisture before they reach this range, and so let fall some of their precious burden upon these needy lands.

It is from this region mainly that the cry for help comes to us, the famine-stricken region of India. We know, even in Canada, how much the supply of rain varies from year to year ; we have our dry years and our wet years, and we know how much hardship the failure through drought, of even one year's crop brings. Most of us, however, have something in store that will tide us over a period of calamity ; but in India the millions upon millions of people who live in these districts of scanty and uncertain rainfall, have nothing whereby to sustain life when the rain fails to come, and the rice without it fails to grow ; and they die of hunger in spite of every effort made to send relief. On the other hand, as if in mockery of the drought-blasted regions, the whole valley of the Ganges has an abundant supply everywhere and always, while to the east in Assam, where the Himalayas join the mountains of Assam, and where the monsoon winds are pressed in between the mountain barriers, the rainfall is enormous, as much as 805 inches fell in one year, 366 inches of this being in July.

Why the supply of rain is so irregular in districts in India, as indeed it is in a measure in Canada too and all over the world, is quite unknown ; some associate the irregularity with the appearance or disappearance of the spots on the sun, or their changing character ; but nothing yet has been proved.

RAINFALL OF TRADE-WIND REGIONS.

The character of the Trade-Wind areas has been already referred to (page 299). The winds lose their coolness in part by becoming more dense as they drop to the earth from the regions of thinner air, and their dryness soon departs wherever they pass over expanses of water. And so wherever they meet the conditions for condensation of their moisture they leave rain; but where these conditions are not present no rain falls. A glance at the map will show us that the desert regions of the world are nearly all beneath the sweep of the Trade-Winds—Sahara, South-western Asia, Lower Egypt, and Australia. These are all countries of very moderate elevation, and though they are not absolutely rainless, yet, except where mountains may exist, as they do in parts of Sahara, the rain can do no more than nourish a very scanty growth of stunted shrubs.

Not all dry regions are due to these winds. We have seen the cause of the Indian desert and of that of western South America; the same cause, viz., the existence of mountains which deprive the winds of their moisture, creates the Kalahari desert, or steppe, of South Africa, the desert of the Great Basin in the south-western region of the United States, and to some extent at least the deserts of Australia.

The "sub-tropical" regions, as the Trade Wind belts are often called, have a rainy and a dry season; for, as has been explained, when the sun moves to the north of the equator, the equatorial belt of rains and calms moves northward too, and the northern Trades retreat before it, thus encroaching upon the regions to the north. Then the southern part of this northern Trade belt has its rainy season, along with its season of heat, while the corresponding region in the southern hemisphere has its dry, cool season. Here, too, in either region where mountains throw themselves across the path of winds, rain follows, be the season dry or wet. "It was the sight of rain on the distant mountains that drove me to become an explorer," said Livingstone, who had gone to southern Africa as a missionary, and who had for months, and even years, worked in the dry regions of the Kalahari desert, where rain falls in such tantalizingly small quantities.

When the sun retreats from our northern hemisphere to give their turn to the Trade-Wind regions of the south, and

our northern winter comes on, the Trades go south too, and that part of the northern sub-tropical belt that had its wet season of equatorial rains, has now its dry season, as we see in the case of the West Indies; while the part that had the Trades forced back on it belongs to the region of cyclonic storms—the region that includes Canada.

RAINFALL IN TEMPERATE REGIONS. Let us look at the depth in inches of the rainfall of Canada, beginning with the east coast.*

Maritime.		*Ontario.*		*Western Canada.*	
Halifax	62.08	Kingston	26.03	Winnipeg	18.14
Sable Island	61.18	Deseronto	36.92	Minnedosa	15.34
Yarmouth	48.81	Lindsay	27.50	Qu'Appelle	15.29
Sydney	46.73	Ottawa	32.41	Medicine Hat	14.13
Truro	46.52	Toronto	28.02	Battleford	12.01
Charlottetown	41.64	Woodstock	29.71	Prince Albert	14.14
Grand Manan	46.63	London	34.80	Calgary	15.12
St. Andrews	40.27	Port Stanley	30.94	Edmonton	14.68
St. John	47.10	Saugeen	32.95		
Chatham	37.61	Gravenhurst	31.71	*British Columbia.*	
Anticosti	40.27	Parry Sound	38.14	Spence's Bridge	7.90
		Port Arthur	22.47	Esquimalt	32.45
Quebec.				Kuper Island	37.42
Father Point	31.49			Port Simpson	96.70
Quebec	35.70			Rivers Inlet	118.72
Montreal	39.87				

This report shows us several things. The eastern Maritime Provinces have a much greater fall than Quebec has; Quebec has somewhat more rain than Ontario; Ontario has more than twice as much as Western Canada; while the Pacific coast is altogether peculiar. At Spence's Bridge, towards the southern interior, only about eight inches fell; at Esquimalt, on the inner side of Vancouver Island, and at Kuper Island, to the south in the Strait, the fall was about as in Ontario; while on the open coast at Port Simpson, near the mouth of the Skeena, and at Rivers Inlet, to the north of lat. 51°, the fall was the great quantity of nearly 97 inches and 119 inches respectively. It may be said, then, that from the Atlantic coast to the mountains of the west the rainfall grows less and less; that the eastern Maritime Provinces have an abundant rainfall, Quebec and Ontario a moderate one, Western plateau Canada a light fall, the mountain region a scanty one, and the Pacific coast an excessive one.

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*The statistics given here and in following pages, unless where otherwise mentioned, are from the Report for 1895 of the Meteorological Service of Canada, R. F. Stupart, Director.

N.B.—"Rainfall" here includes snow—10 inches of snow = 1 inch of rain.

What is the cause of the differences that this report shows, and of the smallness of the rainfall as compared with that of the equatorial regions? Canada lies within one of the wide regions of prevailing westerly winds and cyclonic storms, the regions in which great eddies or whirls break off from the eastward rush of the air high above the ground, and, drawing into their revolving movement the moist, warm air from the sea, which may be hundreds or a thousand and more miles distant, bring needful moisture to countries far remote from the sea and from one another.

The regions of cyclonic storms have a very varied temperature and their average heat is much lower than that of the equatorial regions; hence the air cannot take up and hold as much aqueous vapor as where the heat is greater; and, though we may have heavy downpours of rain, they are only occasional and of very short duration, not of continual occurrence throughout the year or during long periods. In these cyclonic belts, therefore, there cannot be as much rain as where the heat is greater.

Then, wherever the expanse of land is very great there will also be very varied conditions of rainfall. The Maritime Provinces are near the sea, which here is cold, for the Arctic current passes down this eastern coast of America, chilling its waters and making the land cooler than it otherwise would be. The southerly winds—south-east, south, south-west—that the cyclone brings in are at once chilled, and so produce a copious fall of rain, and, as a rule, over a wide area. For the Maritime Provinces are not high ground, and only in the west of New Brunswick does the land reach an elevation of a thousand feet or more; the winds do not deposit their moisture on the edge of the coast alone, but carry it far inland.

Still, it will be seen from the record given in the table above, that Sable Island, Halifax, Yarmouth—places along side of the water—have more rain than the others that are farther away from the front, for there the first chill comes to the saturated air as it blows from the warmer sea; but the winds lose much more moisture as they pass over the higher ground between New Brunswick and Quebec, and, as a result, Quebec has a lower rainfall than the Maritime Provinces.

Further inland it can be only the greater cyclones that have an indraft of moist air from the Gulf of Mexico or the Atlantic; the circles of the cyclone which bring Ontario its usual south-westerly winds must pass over only land, and hence their moisture cannot exist in such quantity as to be at the point of saturation. A south-westerly or a south wind by no means always brings rain to inland Canada, but it is rare that such a wind fails to do so on the ocean border.

South-easterly winds, however, above all other winds give rain; for a glance at the map will show that Ontario is nowhere more than 400 miles from the Atlantic border, and that the indraft of a cyclone to the west and south of the Lakes would bring these winds circling in with their rain over the country. We may get, too, an easterly wind or even a north-westerly one from the ocean, far away as it is. The following is a part of the report on the weather map of February 17, 1903:—"The area of low pressure, which was just north of the Gulf of Mexico yesterday, has moved quickly north-east, and is now centered off the New England coast. A north-easterly snow-storm prevails in the Maritime Provinces." The storm was severe, as its rapid movement shows, and the pressure very low, for the inner isobar around the centre was marked at 28·80. The same north-easterly winds prevailed at Ottawa and Kingston, but the isobar of 29·50, along which they were blowing, passed through Newfoundland and Gaspe; the snowfall, however, was trifling.

The distant West does not get these winds from the Atlantic; the indraft winds in front of the cyclone come from over the land only, and so our North-West interior has but a scanty rainfall, as the record given in the table above shows. If the mountain barriers were not there, interior British Columbia, Alberta, and the other most western parts would have more rain; it would reach them from the Pacific. But now, the front winds of the cyclonic storms coming from the Pacific are at once forced high up into the cold atmosphere, and so drop their moisture abundantly in rain and snow on the outer coast, as we see at Port Simpson and Rivers Inlet, but pass on dry for the

lower regions further inland, as Spence's Bridge tells us, unless where some higher ranges force them still further aloft.

The same conditions prevail in all wide expanses of land in the belt of cyclonic storms; western Europe and eastern Asia have an abundant rainfall, while the interior becomes progressively drier as the coasts become farther remote, until there are only the dry steppes and the sandy deserts far inland. The Gulf of Mexico is most important to the central United States. This region approaches dryness even now. When the sun is north of the equator, the southern portion is dry, for it comes under the influence of the Trade Winds as they back up before the advancing sun; but in winter, just as is the case with southern Europe and northern Africa, both somewhat dry also, it gets its rain from the cyclonic storms; many of these, too, have their origin in the Gulf, or get their moist indraft winds from it. This could not be if land filled the space now covered by the Gulf and Caribbean seas; the southern United States would in that case be at best a steppe. The south-eastern part, including Florida, has much more rain; the ground for the most part is higher, and the Appalachian Mountains, though they lie along the course of the south-west winds, interfere with them sufficiently to cause condensation of the vapor that comes in from the Gulf and from the ocean on the east. The region of the plain is dry for the same reason that Alberta is dry; only the dryness in the former is greater. The Pacific Coast from Oregon down is very dry, for here the mountains deflect part of the westerly winds that come from the Pacific, and send them in an eddy away from the land; only the cyclonic storms of winter bring rain or snow.

RAINFALL OF POLAR REGIONS.

If the cooler temperature of the regions above the tropics of the north and south gives less rainfall than the high temperature within the tropics, still less must be the rainfall of the regions about and within the Polar circles. The cold air can contain only a little vapor, and the fall both of rain and of snow must be light; experience shows this to be the fact. Then if the theory of a very rapid and general eastwardly set of the winds in the circumpolar regions is true, whatever moisture may be in them, is exposed for so long a time to great cold as they whirl round and round the earth in their low spiral, that very little of it indeed must be left to be carried nearer the poles. But we know nothing of these places.

SNOWFALL.

We naturally suppose that in countries or districts exposed to frost the snowfall will correspond to the rainfall, that where the greater rainfall is there the greater snowfall will be. In a measure this is true.

The reports of 1895 (see page 317, note) show that the fall in the Western Territories and Manitoba was very small; one place had 70 inches, very few more than 45 inches; Ontario showed the largest fall, larger somewhat than that of Quebec; out of 120 places in Ontario, over thirty had 100 inches or more of snow, some of these reaching 180 inches, and one, Parry Sound, 203·5 inches. The greatest fall was around Lake Huron and the Georgian Bay.

In the Maritime Provinces, on the other hand, and on the immediate coast of the Pacific, where the rain is the most abundant, the snowfall was comparatively light. Port Simpson and Rivers Inlet had 48·6 and 68·5 inches respectively; while in the Maritime Provinces none of the places that show the highest rainfall had a heavy snowfall. Places back from the coast in both Provinces had a heavier fall than those on the coast. The reason of this difference is that in winter the sea is warmer than the land, and so makes the immediate coast warmer than the districts farther back, and hence the air from the sea is not greatly chilled till it gets at a distance from the coast; while in summer the immediate coast is cooler than the heated land farther away, and so condenses the sea air more than the warmer land would do.

Mountains, of course, have a heavy fall of snow in winter; Spence's Bridge in British Columbia is 770 feet above the sea; it had 7.9 inches of total rainfall, and this includes its fall of 6.6 inches of snow, while Glacier, one of the highest stations on the Canadian Pacific Railway, over 4000 feet above the sea, had the fine fall of 358.5 inches of snow. But the former place is under the lee of far higher elevations, while the mountains at Glacier tower high above all surroundings.

TEMPERATURE.

When we speak of the temperature of a place, we usually have reference to the degree of heat that characterizes it on an average throughout the year. But we may speak of the mean, or average, temperature of any season, or month, or number of months. It is usual to say that the earth is divided into five belts, or *zones*, of temperature, viz., the *Torrid*, lying between the tropics of Cancer and Capricorn, the equator being the line equally distant from both; the *North Temperate*, lying between the tropic of Cancer and

the North Polar Circle; *South Temperate*, between the tropic of Capricorn and the South Polar Circle; and the *North* and the *South Frigid*, enclosed by their respective Polar Circles. But these are only convenient divisions, giving some general idea of the temperature of the regions indicated, the Temperate zones, for instance, embracing wide differences in temperature.

Observations of temperature with the thermometer have been made and recorded for many years past in all civilized countries, at least where Europeans have influence, and from these have been carefully prepared maps or charts indicating mean temperatures for longer or shorter periods all over the world; but these do not show the great variations of temperature in the same place at different seasons.

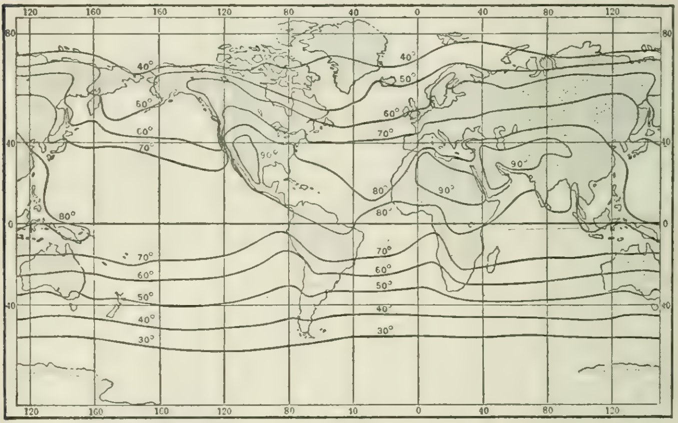


Fig. 148. Isotherms showing mean temperature of the world for July.

Fig. 148* shows the mean temperature of the world for July. The more or less curved lines,—called *Isotherms* ("equal heat")—, pass through all places having the same mean temperature for the month. It will be seen that the places of greatest heat (90°) are largely outside of the torrid zone and in deserts; that the isotherms of 80° enclose a very irregular area approaching Canada with its north-west extremity. In the northern hemisphere the isotherms seldom pass out straight from land to sea, thereby showing the different influence of land and sea on

*It will be readily understood that maps of this kind cannot possibly be accurate except where they deal with countries inhabited by enlightened peoples. And besides a long series of years is necessary in order to determine any reliable mean temperature.

temperature. In the southern hemisphere, where it is winter, the isotherms are nearly straight, for land in great masses is absent toward the cooler south.

Fig. 149, shows the isotherms of January,—summer in the southern hemisphere. In this latter, the isotherms, except at the equator, keep very much the same shape as they had in winter, but they change their position somewhat. The most remarkable difference is seen in the northern hemisphere where the isotherms over the oceans form two great arches, and fall extraordinarily as they cross the land. Nothing can better show the vast influence of the sea on the climate of the northern hemisphere.

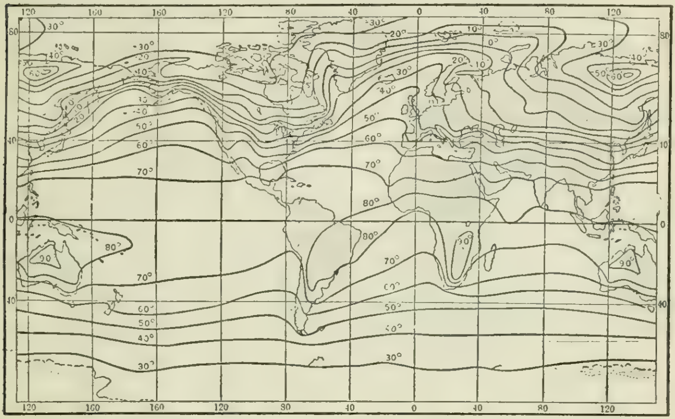


Fig. 149. Isotherms showing mean temperature of the world for January.

The sun is the great source of heat to the earth, and as with every source of heat, the more nearly its rays approach a perpendicular to the object on which they fall, the greater will be their heating power. In other words the part of the earth where during the year the sun is perpendicular or nearly so, viz., within the tropics, is the warmest. But if we imagine the sun to stand right over the equator, we shall see that its rays depart gradually more and more from a perpendicular as they fall on regions farther and farther from the equator: the rays do not fall perpendicularly upon all places within the tropics and then suddenly become oblique at the tropics. The lessening of the heat is so gradual that we cannot distinguish between the temperature of two places unless they are some distance apart.

So again, if we imagine the sun right over Cancer, we shall see that we in Ontario have the sun's rays as near to a perpendicular as the people at the equator have; and on our temperature maps this sends up the tropical isotherm of 70° in July into Ontario and in the North-West much farther north still, even into Saskatchewan. But on the other hand when the sun is over Capricorn, the rays that it sends up to us in Ontario and Canada generally, are very far from a perpendicular. The isotherms that do not at all appear on the map of July are the ones seen on the map of January. The highest temperature for the month of January, 35°, appears in the south-west corner of the Dominion, on Vancouver Island.

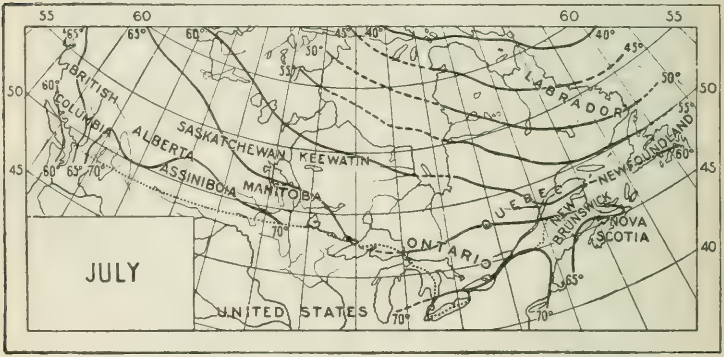


Fig. 150. Isotherms of July in Canada. Note to how high a latitude summer heat extends in the west. Dawson is as warm as New Ontario.—R. D. Stupart, Director Meteorological Survey, Canada.

We see by the July map above, that in July the mean temperature in southern Canada is only ten degrees less than at the equator; but on the 21st of June when the sun is at its furthest point north and its rays are nearest to a perpendicular here, our temperature, contrary to what we might expect, is not so high as it is in July or August, the reason being that in June neither land nor sea is as warm as it will yet become under the summer sun; the winter cold still lingers just beneath the surface. So, too, the heat of summer lingers on in the ground and in the water past September 21, when according to the height of the sun in the heavens, September 21 should have the same temperature as March 21, each being an equinox.

But to get a true idea of the temperature of any place we must know not merely the general, or average, temperature of the year, or even of a season or a month, we must know the temperature of the day and of the night, of each hour in the twenty-four. We know what anxiety there always is about the wheat crop in Manitoba and the West in the summer months of July and August; the isothermal map for July does not show the cause of this: the isotherm of 60° or 70° would seem to indicate plenty of heat; but the daily and hourly records of the thermometer at Regina show that in these critical months for the growing and ripening wheat, the temperature in 1895, though

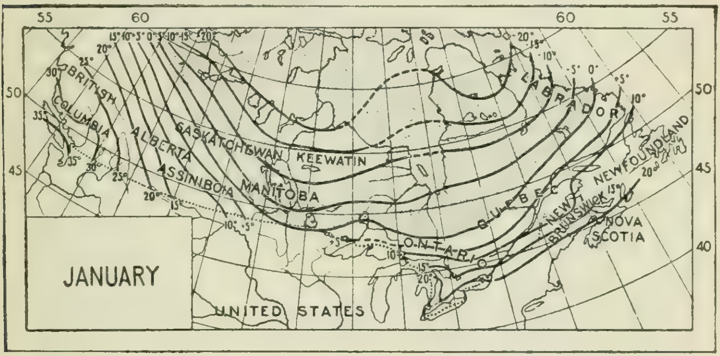


Fig. 151. Isotherms of January in Canada. R. D. Stupart.

ranging during the warmest part of the day (from two to four in the afternoon) from 60° to 93°, yet fell during the night between 2 and 4 o'clock to about 41° in July and 30° in August, thus giving two degrees of frost. Here is a difference of 63 degrees of heat within the two months—an impossibility within the tropics except in the deserts.

In the "danger belt" in northern Florida, lat. 30°, there is always in winter a well-founded alarm regarding the orange crop; for here, too, though the isotherm of 65° passes through it in January, and though so near the tropics, the thermometer drops low at times, in the rear of a cyclonic storm, and blackened orange trees

and worthless fruit are the result of a severe frost. Such a fall occurred on Feb. 17, 1903, when the weather map shows near by a lowest temperature of 20°. A similar disaster sometimes overtakes the growing cotton and tobacco.

Indeed an approach to these extreme conditions of temperature is not unknown within the tropics. At night the forests along the Amazon are chilly through the excessive evaporation of that moist region, and mists gather over the waters and hollows as the cooled ground chills below the point of saturation the layers of air nearest it, but frost never comes. And travellers in the deserts of Sahara and Arabia must take heavy blankets with them, not for the daytime, for then all is glaring hot, but for the night, when under a cloudless sky the bare ground radiates its heat, unobstructed by the vaporless air, till even frost results. 'Tis the same within the tropics in southern Africa, where the morning is far advanced before the natives, who have crawled forth from their comfortless huts numb with the cold of the night, feel warm again.

We must not, therefore, always associate intense heat with the equatorial regions, or only with them. We in Canada have as hot days as those regions have, but the heat is not so continuous with us; it is the dead, long-continued heat of these countries, not its intensity, that drives the English of India to the Neilgerry Hills in the south, or to Simla in the north, in the long sultry season, and that makes a leave of absence for home every few years so needful. We must look to other causes than the direct rays of the sun, or latitude to account for the temperature of a region.

The great heat, as well as the great cold, of the interior of North America, of Canada and the United States alike, is due to its vast unbroken size; beneath the high summer sun, and with its long days and short nights, the ground gets greatly heated; it becomes a wide area of low pressure; but in the nights, short as they are, the radiation is so rapid from the immediate surface, even in July and August, that the freezing point is at times reached before the sun can rise again once more to impart its heat; in September, though the heat by day is as great as in July, the longer nights give longer time for radiation, and, as a result, a night temperature at or below 32° is very common, and it seldom is above 50°. When in winter, with a low sun, the nights are long and the days short, the ground and the air lose more heat by night than they gain by day, and the cold, though interrupted at times by "warm spells," steadily increases till March once more brings the sun into the northern hemisphere.

The sea-board has not so great varieties; the Maritime Provinces have a winter temperature several degrees higher than places in the same latitude far inland, but a lower summer temperature. In 1895 the mean temperature of Halifax from April to September, inclusive, was 55·9°; for the other months, 32·8°; of Orillia, in the same latitude, 57·8° and 24·4°, respectively; of Yarmouth, 53·5° and 34·4°, for the same months, respectively; and for Toronto, in the same latitude, 59·7° and 28·8°. The same differences are seen in Europe between the climate of England and that of the interior. The reason is the neighborhood of the sea. The sea gives off its heat more slowly than the land, and, as there is a continual circulation of the waters, they remain at nearly the same temperature, or, at most, slowly change.

CLIMATE.

It is the varying conditions of the atmosphere, of its temperature, its winds, and its rainfall, that make up what is termed "climate." There are the great general conditions that apply to wide regions or divisions of the earth as a whole, and then there are the particular conditions that apply to smaller divisions or individual places, and these vary indefinitely; so that in order to know the climate of a particular place, we must know its particular physical conditions, and the results these conditions bring about.

Latitude,—distance north or south from the equator,—determines climate only in a very general way in regard to the temperate zones. Southern England is in the latitude of Winnipeg; but extreme cold is unknown in southern England; flowers bloom all the year round out-doors, and snow is rare in the Isle of Wight; fuchsias are a carefully protected house-plant with us, but in southern Ireland they grow out-doors into large shrubs. On the other hand, we in southern Ontario grow in the open air, tomatoes, peaches, grapes, and apricots as ordinary crops; this cannot be done in England except as wall-fruit. These fruits require a degree of heat in summer which is found in Canada but not in England, though the mean temperature of the whole year is much higher in England than in Canada.

Our insurance companies will not, as a rule, allow those whom they insure, to go to the West Indies during the summer, especially to Cuba, but they are free to go from October to April. For in the summer months when the belt of greatest heat moves northward, it brings the dead, sultry, moisture-laden winds with it, and the rank vegetation in its rapid decay in such an atmosphere, fills the air with fevers deadly to those who are not hardened to the climate; but with the retreat of the sun southward, the cooler winds from the north, the Trades, come with their life-giving breath.

It is the same on the Guinea coast; the wet, sultry summer winds give rise to deadly malaria in the dense steaming jungles of that region; and the old refrain,—

> "Oh the Bight of Benin, the Bight of Benin,
> For one that goes out there are ten that go in!"

tells the sad experience of English traders to that region. But when the season changes, the retreating sun lets the Trade Winds blow there; and their dryness and heat, intensified by their passage over Sahara, though they crack the skin of the natives till it peels off, dries the country and the malaria disappears.

So also if we wish to have a correct knowledge of the climate of interior Canada we must know something more of it than that the rainfall is scanty, the heat of summer intense, the cold of winter severe, and the range of temperature between the nights and days very great. The rich yield of wheat and other grains from the great plains of that region shows there must be something more.

It is a land of sunshine:—The month of June shows over 40% of possible sunshine, July over 53%, and August 60%. And then though the total rainfall of the year is light, yet the greater part of it comes when it is needed for the growing crops; in 1895 in the four critical months of May, June, July and August, Indian Head had 18 days on which rain fell, Brandon 33, and Winnipeg 40. These figures may not be exactly the same for every year, yet they clearly show this feature of the climate, a feature that points to what this western country must continue to be,—a vast grain-growing region. There is indeed a possibility of an occasional light frost at a critical period, yet not severe enough to produce total destruction of the crop, or wide-spread enough to cause general disaster, nor yet frequent enough to render farming too hazardous an occupation.

MOUNTAIN CLIMATES. In the torrid zone lofty mountains have all degrees of temperature—hot, moderate, cold, from perpetual heat to perpetual frost, with all the different productions that belong to the varied climates, from tropical fruits to polar mosses. The moisture is greater, however, than in similar temperatures on the plains, for not only do the mountains send the winds into higher and cooler regions, thus making them part with moisture, but their own coldness serves also to cause rainfall. Those who have been in mountainous countries have often seen rain or snow drifting along the trend of a ridge, but not falling to the valley below. But although on mountains in the torrid zone there may be the temperature and the rainfall of the temperate zones, there are not the cyclonic storms or the change of seasons that we know so well;—it is only perpetual summer, perpetual spring, perpetual winter.

The mountains of the temperate zones, like those of the torrid zone, have a more intense sunlight than do the plains, for the thinner, comparatively dustless and vaporless air allows more of the sun's rays to pass through than is the case on the low ground. But different from the mountains of the torrid zone is the greater windiness of the mountains of the temperate zone—they do not lie, as do the former, in the region of ascending air, but in the region of currents flowing parallel to the earth's surface.

ISLAND CLIMATE. The characteristic feature of the climate of islands is its small range of temperature; for the sea, even in high latitudes, has only a slight range of temperature; indeed the daily island temperature more nearly approaches the mean temperature of the region in which they are situated, than is possible in an interior country. Naturally, island climate is more moist than an inland one, for the quick-cooling land will condense the moisture-laden air of the sea and cause rain. In some of the islands of the northern Pacific where the temperature is low, but with little range and little wind, a dull moisture pervades the air, and so heavy that in a few minutes it will wet ordinary clothing quite through.

Similar to island climate is coast climate. In southwestern British Columbia at not one place on the open

coast, or in one inlet or low-lying valley into which the warm winds from the Pacific penetrate, does the thermometer sink to zero in winter. It is no wonder then, that though south-western British Columbia is some 400 miles north of

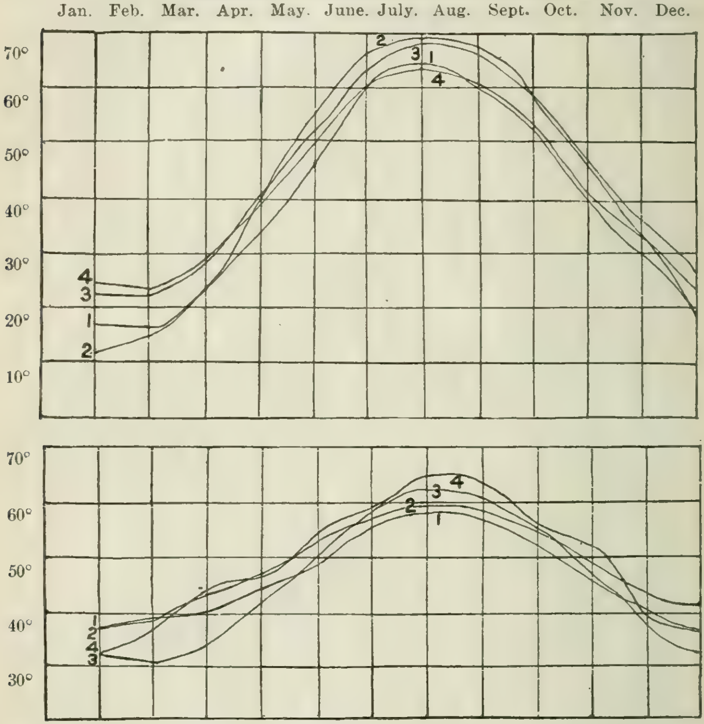


Fig. 152. Curves showing the monthly variations in temperature of certain places in Europe and Canada. Mean annual temperature given in brackets

Upper division:—1. St. Petersburg (38°.7); 2. Montreal (41°.8); 3. Toronto (44°.2); 4. Christiana (41°.6).

Lower division:—1. Edinburgh (46°.4); 2. Victoria, B.C. (48°.6); 3. Copenhagen (45°.4); 4. Agassiz, B.C. (48°.9.)

Toronto, its valleys and sunny hillsides can raise fruits that can be raised in Ontario only in its extreme southwest.

Thus we see how very many conditions enter into the consideration of the climate of a place.

CHAPTER VIII.

LIFE.

If the earth originated in the manner supposed by the nebular hypothesis, many ages must have elapsed after the formation of a crust on its surface before it was in a condition suitable to maintain life. When the first stratified rocks were being laid down, the temperature of the ocean may have been as high as 300 degrees centigrade, the pressure of the atmosphere being much greater than at present; hence at that time, and probably for very long after, dead matter alone existed. The activities induced by that vital principle, called life, were probably first manifested in an unconscious form in the plant, and later in a conscious form in the animal. We may look upon the plant life of our world as earth matter so transformed chemically by the life principle as to constitute the animate plant body, and as long as this life principle is present, the plant has the power, under suitable conditions, of assimilating earth matter, and thus maintaining its existence. When conditions become such that assimilation cannot be carried on, the plant is said to die, and the matter of which it is composed becomes a portion of the earth again.

Just as the plant-body may be viewed as a chemical laboratory for the transmutation of the raw material of the earth into vegetable tissue, so the animal body may be regarded as a chemical laboratory, in which the raw material of the plant world is transformed into the constituents of the animal organism. Out of the raw material of the earth and its atmosphere the plant manufactures certain compounds known as *proteids*. These substances are as essential to animal life as to plant life, but the plant alone can produce them, hence the animal world depends, in the strictest sense, entirely upon the vegetable world for its maintenance.

The differences between the ordinary plant and the ordinary animal are very evident, but between the lowest

plants and the lowest animals little if any difference is discernible. Generally speaking, most animals have the power of voluntary movement, possess intelligence, and many of the higher forms are capable of reasoning, while most plants are stationary, and do not exhibit a conscious intelligence. Both animals and plants have the power of detaching from the adult body reproductive portions, which, under suitable conditions, will develop into new individuals closely resembling the parent.

CLASSIFICATION. On a close analysis it is found that both the plant and the animal kingdom may be divided into a number of natural groups, the members of which show a gradual advance in structure from the simplest forms to those more complex and highly organized. These groups include sub-kingdoms, classes, genera and species. A *species* includes a number of individuals all of which are practically alike. A number of different species closely related constitute a *genus*, and a number of related genera form a *family*. For example, if we look into a field we may see thousands of tall buttercups. These all belong to one species. If we walk through the field we may see a number of creeping buttercups, slightly different from the tall ones. These form another species, of which there may be thousands of individuals. Again, if a slow stream run through the field we may find a white buttercup growing in the water, which forms a third species. Now, these three plants, while differing from one another sufficiently to form distinct species, are enough alike to be included in one genus. If the field border on the woods we may find on the high ground some hepaticas, and in a low place some marsh marigolds. Neither of these is sufficiently close to the buttercups, nor to each other, for all to be placed in one genus, but they are all enough alike to form three genera of the same family.

CLASSIFICATION OF PLANTS.

(1) CRYPTOGAMS—Flowerless plants.
 Moulds, Bacteria, Diatoms, Sea-weeds, Fungi, Algæ, Lichens, Mosses, Ferns and Horsetails.

(2) PHANEROGAMS—Plants producing flowers.
 (a) *Gymnosperms*—Seeds not enclosed in an ovary.
  Pine, Spruce, Cypress, Cedar.
 (b) *Angiosperms*—Seeds inclosed in an ovary.
  All the ordinary flowering plants.

CLASSIFICATION OF ANIMALS.

(a) *Invertebrata*—Animals without a back bone.
Protozoa—Amœba, Infusoria, Foraminifera.
Porifera—Sponges.
Cœlenterata—Jellyfish, Hydra, Corals.
Echinodermata—Starfish, Crinoids, Sea-urchins.
Vermes—Worms.
Arthropoda—Lobster, Spider, Centipede, Insects.
Mollusca—Clams, Oysters, Snails, Cuttlefish.

(b) *Vertebrata.*
Fishes—Salmon, Shark.
Amphibians—Frog, Salamander.
Reptiles—Turtle, Snake, Lizard, Crocodile.
Birds—Crow, Condor, Ostrich, Sparrow.
Mammals—Kangaroo, Sloth, Elephant, Whale.

PROGRESSIVE DEVELOPMENT. If we make a minute examination of a type of each of these great primary groups into which the plant and animal kingdoms are divided, we shall observe a gradual advance in structure from simple units, without apparent organization, and consisting of a small mass of a viscid, semi-transparent substance called protoplasm, to forms of a highly complex organization in which there is a great division of labor, by a diversity of organs, each of which performs its own special function. In the animal kingdom, for example, the *amoeba* consists of a single cell and possesses no organs. It eats and digests food, but has neither mouth nor stomach; it feels, but has no nervous system, and moves from place to place without locomotive organs. The whole animal, as a unit, does all these things. The little fresh-water *hydra* takes the form of a tube, and is made up of many cells. One end of the tube acts as a mouth, the other end is closed and serves as a creeping foot, or disc, and the rest of the tube forms a digestive sac; it also has tentacles with which to seize food particles and direct them towards the mouth. In *insects*, the appendages are more numerous and more highly specialized; some are adapted for flying, and some for walking, while others supply food particles to the mouth; but they perform their function in a much more perfect manner than the tentacles of the hydra. Finally, in the *vertebrates*, we see organs adapted to the most complete division of labor, and, for the first time, an internal bony skeleton supporting the soft parts of the body.

Not only is progressive development a characteristic feature of the animal and vegetable kingdoms taken as a whole, but it may be seen in each class, and often an individual will show a gradation in form between two species, making it difficult to determine whether it should be classed with this species or with that.

We know that the forms of life on the earth at the present time are the descendants of those that preceded them, and these, in their turn, are the offspring of still older generations. From an examination of these ancient organisms which have been preserved as fossils in the rocks of different ages, it is found that the oldest rocks contain the simplest fossils, and that, in general, the more highly organized plants and animals flourished on the earth at successively later periods in its history. In the very oldest *Primary* rocks, the *Cambrian*, we find multitudes of well-preserved fossils of animals that lived when these rocks were being laid down. These include low types of nearly every class of *invertebrate* animals, but not a single *vertebrate* has so far been found. The first of the latter occur in the Silurian rocks and belong to *fishes*—the lowest class of vertebrates. Next we find *amphibians*, and then *reptiles* towards the close of the Primary Age. Reptilian *birds* appear at the beginning of the Secondary but true birds are not found until towards the end of that age. Low forms of *mammals*, the ancestors of the present Australian types, occur first in the Secondary, and it is not until the beginning of the Tertiary that we discover traces of the higher mammals. Finally, *Man* himself appears shortly after the close of the Tertiary.

As with animals so with plants, the same gradual advance from low to high, from simple to complex, is to be observed. In the Cambrian the only plants are *sea-weeds* with simple tissues. Flowerless *cryptogams* first appear in the *Silurian*, and become very abundant in the *Carboniferous*, their fossils forming the coal we burn. Plants with naked seeds, like the pines, soon outstripped them however, and became the prevailing type of the forests of the Secondary age. Towards the close of this age the great class of *flowering plants* put in an appearance, and are now at the period of their greatest development.

DESCENT WITH MODIFICATION. Only the most recent deposits contain the remains of organisms similar to those now living. As we go deeper down into the rocks we meet with forms which differ considerably from those in the superficial deposits, and the older the rocks the greater the difference in the fossils, until we see before us the remains of a plant world and an animal world presenting many features entirely new to us. For example, in place of the horse with which we are familiar, we meet with fossils of three-toed and four-toed horses. Instead of the elephant we have his ancient relation the mastodon, and the typical bird gives place to peculiar toothed forms possessing many distinctly reptilian characters. Some of our well-known animals we do not find represented at all, but in their stead are certain *composite types*, which combine the characters of several different modern forms in one. There is a generalized type embracing the characters of the antelope and the giraffe; another possesses features common to the rhinoceros and the tapir.

Thus two great and apparently closely related phenomena confront the naturalist, demanding an explanation: —

(1) The gradual advance in organization of living plants and animals from simple to complex.

(2) The order of occurrence of fossils, the simplest and least specialized occurring in the oldest rocks, succeeded by higher and still higher forms as we approach the more recent deposits.

To these may be added a third, namely, the fossils of a country are generally closely related to the living forms which still inhabit it.

In 1859 Darwin published his remarkable book entitled the "Origin of Species," in which he offered an explanation of these facts, and his theory is widely accepted by naturalists to-day.

This theory states that life first appeared on the earth at a time indefinitely remote, and that it was of the simplest kind; that all of the countless generations of plants and animals that have lived since, are descended from those

which preceded them; and that as these organisms succeeded one another they became varied and complex in structure, resulting in the multiplicity of forms seen on the earth to-day.

This modification of form is the result of *heredity* and *environment*. Although the offspring of plants and of animals are like their parents in structure (heredity), yet some of them may vary in some degree from the parent form. Under ordinary circumstances this slight variation will not affect the well-being of the organism, but under the influence of some *new environment*, such as change of climate, change of locality, severe competition for food, or a struggle with enemies, this slight variation in structure may make the possessors of it better fitted to cope with the new conditions; hence they will be more likely to survive and to adapt themselves to these new conditions, than those individuals that do not possess it. They will also, in obedience to the law of heredity, transmit their peculiarity to their descendants, and in due time it will become general. In another generation or two, from excessive competition or the introduction of adverse conditions, individuals with some new and advantageous peculiarity will be the favored and successful ones. If on the contrary this slight alteration in structure, should render an individual less fitted for its environment, its chances of surviving and of leaving offspring will be less.

In this way the constant struggle for existence leads by a process of *natural selection* to the *survival of the fittest*. Thus, during the lapse of ages, and under continually changing conditions, plants and animals have been produced differing widely both in structure and in habit from one another and from their original ancestors.

When the conditions of life become such that a species of plant or animal cannot exist, it must do one of three things: (1) migrate to some place where conditions are more favorable; (2) adapt itself to the changed conditions, or (3) become extinct.

The struggle for existence causes each species to endeavor continually to extend its range. In order to do this the first condition necessary is some *means of dispersal*.

DISPERSAL OF ANIMALS. In the case of animals capable of roaming long distances on foot, or of those that can fly well, or swim well, the means of distribution are evident. Birds have an advantage over mammals in their ability to cross considerable bodies of water, and in many cases to cross high mountains and wide deserts. Reptiles and amphibia are almost as limited in their means of dispersal as mammals. At times however their eggs may be carried by floating material of various kinds for long distances. Insects have an advantage over most other animals in spreading over wide areas. Storms often carry them great distances, and their eggs and larvae may be transported for thousands of miles in the crevices of tree trunks or in other floating material. They have, therefore, as might be expected, an extensive range. Bats, seals and whales have also, for obvious reasons, a wide distribution.

DISPERSAL OF PLANTS. Many plants, owing to the nature of their fruits and seeds, have means of distribution superior to those possessed by most animals. Light seeds such as those of orchids, or seeds with downy appendages as those of the daisy, thistle, and willow may be borne long distances by the wind. The fruits of the maple, elm, and pine are provided with wing-like expansions which aid dispersal. In some cases whole plants, as, for example, the so-called "tumble weeds," and the Russian thistle, when dead and dry but loaded with seeds, may roll for many miles before the wind, scattering their seeds as they go.

Animals in their migrations act as most effectual agents of plant distribution, by carrying, attached to their coats, fruits or seeds provided with hooked spines or awns, or by depositing in suitable soil the indigestible seeds of stone-fruits and berries. Birds often convey seeds from place to place in mud attached to their feet. Darwin cites a case where he grew 82 plants from the seeds contained in a dried mud-ball taken from the leg of a lame partridge. Fruits which will withstand the action of water for a long time may be carried from one continent to another by ocean currents. A notable example of this is the cocoanut which

is kept afloat by means of its fibrous coating. As a consequence, the cocoanut-palm is usually the first tree to appear on newly formed coral islands.

ADAPTATIONS. Besides the power of dispersal there is another very important factor in the distribution of a species. In order to survive it must be able to maintain itself and to adapt itself to the conditions of its new home. These may mean new foods, or new enemies, and probably greatest of all, the competition with allied forms that have already adjusted themselves to surrounding conditions. Most of our Canadian birds migrate to the south when the cold of winter approaches; the Canadian jay however has succeeded in adapting itself to the climate and hatches out its young in midwinter. An adaptation of arctic and subarctic animals to changed conditions is seen in the extra coat of fur some provide themselves with as the temperature becomes lower. Others hibernate, that is, pass the winter in a condition in which the functions of the various organs are almost suspended, and the body can endure great cold without injury. Attempts have been made to introduce the English lark and nightingale into North America, but owing either to an unfavorable climate or to competition of native birds, the attempts so far have been unsuccessful. The competition of the English sparrow on the contrary is proving disastrous to many Canadian birds. The "lady bird" beetle, introduced into California from Australia to destroy an injurious scale insect, lived well and multiplied rapidly as long as the scale insect was plentiful, but as the latter became scarce the beetle could not accommodate itself to new food, and was soon on the way to extinction.

Man is probably the greatest enemy animals have to contend with, and the effect of his destructiveness is seen in the gradually diminishing numbers of nearly all kinds of large game. The Dodo, a large bird that once inhabited Mauritius island in great numbers, fell a victim to swine introduced by a ship's crew. The American Bison, or Buffalo, that once ranged in countless herds over the plains east of the Rocky Mountains, is now practically extinct, and for some cause the passenger pigeon is fast disappearing from North America.

In the plant world the struggle for existence is even more perceptible than in the animal world. For every plant which succeeds in reaching maturity there are

thousands that fail. By overcrowding, plants get rid of hosts of their weak neighbors. What are commonly called weeds, such as burdock, dandelion, quick grass, thistle, etc., are merely sturdy plants, most of which have been brought to this country from Europe where they had centuries of experience contending for the mastery. The farmer and the gardener know only too well how persistent such weeds are in striving for an advantage, and how little chance the useful plants, when unaided by man, have against them. What collector has not seen some favorite little colony of a rare flower become smaller and smaller as he visits it each season, until at last a season comes when he looks in vain for a single blossom, and instead of his familiar friends he finds some hardy weed in full possession of the ground upon which it had been encroaching for years. Tribes of parasitic plants are continually feeding on other plants and all animals get their food directly or indirectly from plants. The species best fitted to overcome obstacles will have the widest distribution. There are some noted examples of the spread of European plants over thousands of square miles of territory in Australia and South America. The Russian thistle has within twenty years become a formidable pest in portions of the United States.

In order to survive under adverse conditions plants, like animals, must adapt themselves to their environment. The deciduous trees of the temperate regions become inactive and dormant during winter. Leaves and buds have waxy coatings, and stems and roots develop cork for protection. Desert plants, such as the cactus, are often leafless to prevent evaporation, and are provided with means of defence against herbivorous animals. Arctic and alpine plants lie close to the ground, and soon become covered with snow, which protects them from the extreme cold. Many plants like rag weed and smart weed are unpalatable. Others like the barberry, thistle and nettle protect themselves by thorns, prickles or stinging hairs.

BARRIERS. The means of dispersal at the command of even those animals and plants least efficiently equipped would soon enable them to widen their range indefinitely and thus become universal. That they do not do so is

owing to obstacles or *barriers* of some kind which determine the limits of each species.

Sloths and monkeys, which are arboreal forms, are not apt to cross deserts or open plains. Deserts also form a barrier to animals like the beaver and the otter, which must live near water. Large rivers determine the range of some animals. Two species of monkey live on opposite sides of the Amazon, and have never been seen in each other's territory. Few land animals can swim across any considerable arm of the sea, hence oceanic islands are usually without mammals, reptiles, or amphibians. Continuous ranges of high mountains form an effective barrier to the majority of both plants and animals. In the elevation of mountain chains individuals of the same species may become separated and develop new species. In this way the various species of mountain goats are believed to have been developed through variation from a common ancestral form.

ORGANIC BARRIERS. Sometimes one type of organism may affect the distribution of another, or of several others. Goats brought to St. Helena destroyed all the trees and shrubs on the island, and thus the insects and birds dependent upon them disappeared. Paraguay has no wild horses or wild cattle on account of an insect which attacks the young of both. This will affect the vegetation of that country, and incidentally the birds and insects. In parts of South Africa no cattle, horses or dogs can live on account of the Tsetse fly, while zebras and antelopes are not affected by it. Hence, for the former animals this insect pest is an impassable barrier to this region.

EFFECTS OF CLIMATE. Climate restricts the distribution of many types; thus apes, lemurs, and related forms, are seldom found farther north or south than about 15 degrees from the equator, and arctic animals, such as the polar bear and the arctic fox, are never seen south of the timber line.

CLIMATE—ADAPTIVE GROUPS. The influence of climate on the form, color, and habits of almost all kinds of life is often very marked, producing a superficial resemblance amongst forms in no way structurally related; thus, we recognize tropical, temperate, and arctic *faunas* and *floras*. In tropical regions where the climate is warm and moist the whole year, there is usually a dense forest growth. Tall, leafy evergreens almost shut

out the light from a bewildering variety of orchidaceous epiphytes, almost colorless parasites, and huge creeping vines which entwine themselves like great cables about the larger trees, the whole presenting a degree of luxuriance unknown outside of the equatorial regions. Here a congenial home is provided for myriads of heat-loving animals of various kinds, birds with gorgeous plumage, and brilliantly colored insects.

As we pass into the temperate zones, the forest growth becomes less dense, the trees lose their leaves as winter sets in, and only pines and related species remain green throughout the whole year. This change in vegetation is accompanied by a diminution in the numbers and varieties of the animals. Their habits show an adaptation to new conditions. Many of them migrate during the cold season, others hybernate, still others take on a thicker coating of hair, fur, or feathers.

As we approach the arctic latitudes, the ordinary deciduous trees become less numerous, and are replaced by hardy cone-bearing trees, and finally these disappear along with all other vegetation, except mosses, lichens, and dwarf shrubs. Animal life also disappears, with the exception of a few arctic forms that are specially adapted to a severe climate, and whose color harmonizes with their surroundings.

VERTICAL DISTRIBUTION. On ascending high mountains we meet with changes in the animals and plants, especially the latter, similar to those met with in going from lower to higher latitudes on the plains. Thus, at the foot of the Himalayas, tropical life prevails; higher up, forms characteristic of temperate regions are found, and at the snow-line arctic species are the characteristic ones.

Thus, climate roughly divides plants and animals into great *adaptive groups*, composed of individuals of many different types. In a more restricted sense we have adaptive groups peculiar to deserts, open plains, lake regions, etc.

Of all barriers to the distribution of life, *oceans* are the most important, not only because they are impassable to nearly all forms of land life, but because they are believed to have always occupied their present beds, though they have often covered land which is now elevated above the

water, while other lands, once above water, are now buried at various depths beneath its surface. For countless ages, then, the oceans must have separated the life forms of distant continents from each other, and it is found that the continents separated by the greatest extent of ocean present the greatest contrasts in their plant and animal life, while those less completely isolated have a greater similarity between their chief types.

ZOOLOGICAL REGIONS.

It was formerly the custom amongst naturalists to divide the earth's surface into great climatic belts or zones, and to consider the animals inhabiting any particular zone essentially alike all the world over, without taking into consideration any differences in structure, or any relationship that might exist between them. Now, while climate has great influence in determining the habits and adaptations of animals, it falls very far short in accounting for the way in which the various *kinds of animals* are dispersed over the globe. It does not explain why certain types are found *here*, and not *there*, while others abound *there*, but not *here*. Countries very similar in climate and physical features may have very different animal inhabitants. It would be difficult to find two regions more alike in climate and abundance of vegetation than tropical Africa and tropical South America, yet they differ very much in their animal life. The former has giraffes, elephants, and guinea-fowl; the latter tapirs, sloths, and toucans. Parts of Australia and South Africa are extremely alike in all their climatic conditions, yet the animals found in each are extremely unlike. One has only kangaroos and their relations; the other has antelopes, lions, and hippopotami. Again, we find large groups of animals distributed in a most perplexing manner for which climate offers no solution. Why are marsupials, with the single exception of the American opossum, confined to Australia? Why are tapirs now found only in South America and the Malayan islands, two regions on almost opposite sides of the globe? Why are ostriches limited to Africa and South America, lemurs practically to Madagascar, humming birds to America, and camels to South America and Asia?

To answer these and many other similar questions relating to the present distribution of animals, several factors have to be taken into account. Besides those already mentioned, namely, descent with modification, means of dispersal, and the different barriers to migration, we must know something of an animal's *habitat*, that is, its native place, also its *range* at the present time; we must also know its *geological history*, as well as that of its immediate ancestors. In addition we must have some knowledge of those great *earth-movements* which from time to time have affected the relations between the continents and oceans. "The permanency and great antiquity" of the continents and oceans have already been remarked.

There is good geological evidence for believing that during the whole of the Tertiary period "the great land masses of the earth were, as now, situated in the northern hemisphere;" *and that here the mammals, and all the other great types of vertebrate life were developed*; that in the southern half of the globe there stretched out three smaller land masses, not always so permanent in their boundaries as the great northern continents, but always distinct from one another, and approximately represented by Australia, South Africa, and South America; and that *each of these southern continents received successive influxes of animal life from the northern hemisphere during successive periods of land connection with it.*

The periods of union between the northern and southern land areas appear to have been of short duration compared to the periods of isolation. During the latter the various animals in the northern hemisphere, owing probably to their greater numbers and hence keener competition for food, developed more rapidly, and produced higher and more varied types of life than those in the smaller land masses of the southern hemisphere. Here the various immigrants from the north retained their original character for a longer time than those left behind, consequently when the next land connection occurred, and a fresh influx of the more advanced northern types invaded the south, the more lowly-organized inhabitants of the latter failed to compete successfully with the invaders, and thus they became much reduced in numbers, if not completely exterminated.

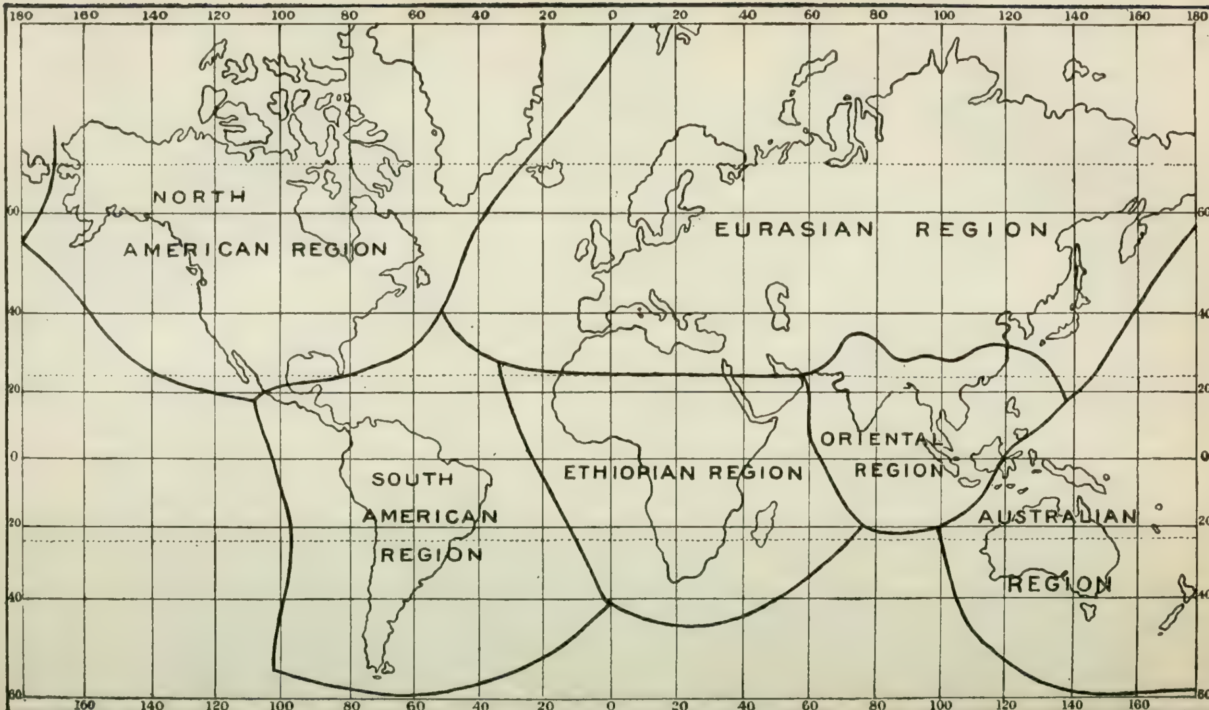


Fig. 153. Regions of Distribution of Animal Life.

A consideration of all the various factors in the distribution of animal life, makes it possible to mark off the earth into six great zoological regions, or faunal realms, as follows: —

(1) Palæarctic or Eurasian, (2) Nearctic or North American, (3) Neotropical or South American, (4) Ethiopian or African, (5) Oriental or Indo-Malay, (6) Australian. From the boundaries of these as laid down by Dr. A. R. Wallace on the map (page 344), it will be seen that they agree pretty well with the chief geographical divisions of the globe, except that in Africa a great barrier, the Sahara desert, cuts North Africa off from the Ethiopian region and gives it to the Eurasian, and in Asia the Himalayan barrier separates the Oriental region from the Eurasian. The Australian region alone is sharply defined. Around the others is a zone of debatable ground with a mixed fauna of forms common to adjacent regions.

Attention will be directed chiefly to the distribution of the mammals, as they are the most restricted by great natural barriers, and have few accidental means of dispersal; hence, their present range should depend in a great measure on the past changes and present physical features of the earth's surface. They also occur in great abundance as fossils, and thus furnish a key to the solution of many apparent anomalies in existing distribution. The divisions as given on the map also answer in all important particulars for the geographical distribution of birds, reptiles, and amphibians. A brief reference will now be made to each region, beginning with the Australian, whose fauna is the simplest.

AUSTRALIAN REGION. This region is completely isolated from all others and as a consequence has many peculiar and striking features. It was probably during some part of the Secondary epoch that Australia had land connection with Eurasia, and became stocked with the ancestors of the egg-laying and the kangaroo-like or pouched mammals found there to-day. These were then widely distributed over the northern continent and were probably the prevailing form of life. From that time until the present there seems to have been no further land connection; and these low forms of mammalian life, while

falling by the way in their struggle for existence in the great northern region, became wonderfully developed on their island continent during Tertiary times. Remains of extinct animals of gigantic size have been found—kangaroos, larger than any now living, also many related forms almost as large as elephants, all of the marsupial or pouched type. Fossils of huge birds of a low type, related to the apteryx of New Zealand, also occur in Tertiary deposits.

Descendants of these ancient forms, along with a few others possessing exceptional means of dispersal, constitute the fauna of the Australian region at the present time. The marsupialia, with the exception of the American opossum, are confined to this region, and have assumed a great diversity of form and habit. They comprise over 100 species; some are carnivorous, while others are herbivorous. There are arboreal and terrestrial forms; some resemble wolves, others have the appearance of marmots, weasels, and flying squirrels. Australia also possesses some very characteristic birds, such as the emu and cassowary, (allied to the ostriches), the curious mound-builder whose enormous eggs are hatched out in piles of decaying vegetable rubbish with which the bird covers them, the laughing kingfisher, numerous parrots, birds of paradise, honey-suckers, and many gaily colored pigeons. Reptiles and amphibians abound, and many of the snakes are venomous.

SOUTH AMERICAN REGION. The character of the life of this region indicates a long separation of South America from the rest of the world, with occasional periods of land connection with North America. The present union dates from Pre-Glacial times. But long before this, during some period of the Secondary epoch, it was supplied with the ancestral forms of its edentates (low types of quadrupeds including sloths, ant-eaters, and armadillos), and such rodents as cavys, guinea-pigs, and agoutis, at a time when these were the highest mammalia on the globe. A period of long isolation then followed, in which they developed into the unwieldly creatures whose huge fossils may be seen in the museums at La Plata and elsewhere in South America. In early Tertiary times

communication appears to have been again established, and the ancestors of the existing marmosets, and of low-type monkeys with prehensile tails, entered from the north. Later it received its camels, peccaries, mastodons, and lions from the same source, and afterwards, just before the Glacial period, its bears, tapirs, opossums, antelopes, and horses, the two latter of which have become extinct.

Thus, like Australia, South America has been stocked by immigrants from the north, and the conditions of existence have been such that these have not undergone improvement to nearly the same extent as those left behind. The same relatively low type of organization is characteristic of the South American birds. Many of the Eurasian song-birds are here songless, while the rhea and the curassow are allied to the emus and mound-builders of Australia, all of which, with the African ostrich, "are probably divergent modifications of a once widely distributed type."

AFRICAN REGION. A glance at a map of the world will show that Africa, like South America, is almost separated from the great mass of land in the north. There is geological evidence that in early Tertiary times the separation was much more complete, and that all of North Africa and most of the Sahara desert then formed a continuous sea. At the same time South Africa extended much farther towards the south-east so as to include Madagascar, and an extensive land area now marked by a few islands. The inhabitants of this isolated continent were probably similar to those of South America at the same period. The higher types of mammalian life were absent, while their places were taken by lemurs, insectivors, and lowly organized ant-eaters. Amongst low forms of birds were the dodo, now extinct, and the ancestral type of the ostrich which once had a very wide distribution.

This condition of affairs lasted a very long time, but at length a change came; the northern part of the continent was elevated above the water; what are now the Mediterranean and the Red seas became bridged across; and the advanced mammalian types of Europe and Asia poured into

Africa, completely overrunning it. Descendants of these form the characteristic African fauna of the present day. The hippopotamus and giraffe are found no where else in the world. Besides numerous species of antelope, the elephant, the rhinoceros, the lion, and the zebra abound. In the deep forests man-like apes, including the gorilla and the chimpanzee, are found; a few lemurs and insectivors still survive.

These last two families are especially characteristic of the island of Madagascar, which may be said to be the *home of the lemurs*. Madagascar was separated from the continent by a deep-sea barrier before the great invasion of Eurasian forms ; hence none of these forms are found in this or the adjacent islands. This accounts for the long survival on several of these islands of such a stupid and defenceless bird as the dodo.

A peculiar feature of tropical African fauna is the complete absence of bears, deer, and goats. This is accounted for by the line of immigration having always been, as now, through desert regions which are unsuitable to these forms. Amongst peculiar African birds are the ostriches, secretary bird, guinea-fowl, vulture, and plantain eater.

EURASIAN REGION. This region is composed chiefly of Europe, and Asia north of the Himalayan mountains. It also includes North Africa, which was formerly united with it, and which is now separated from the rest of Africa by the Sahara desert.

A study of the fossils preserved in the rocks of this vast territory, leads to the belief that it is *the original seat of development of vertebrate life*, and probably of the highest forms of invertebrate life as well. Not only do these extinct animals comprise the ancestors of the principal forms now living in this region and in North America, but in the deeper strata we find the ancestral types of the present fauna of the southern continents. It has had, at one time or other, land connection with all the other great regions, and is the source from which, at different times, they were supplied with the higher forms of life.

Compared with Tertiary times, the animal life of Eurasia is now very much impoverished. The climate was then everywhere favorable, and the teeming wealth of mammalian life, especially in the Miocene and Pliocene eras, can scarcely be conceived of. Animals now confined to Africa and the Oriental realm, together with hosts of extinct types, were then characteristic of this whole region. Elephants and lions, rhinoceroses and hippopotami, roamed through the forests, or wallowed in the rivers of Great Britain which was then connected with the continent. For hundreds of thousands of years, all through the Miocene and most of the Pliocene period, these animals lived and multiplied without any important break in their continuity; then gradually, in late Pliocene and Post-Pliocene times, many of the most remarkable became extinct or left the country. The most reasonable explanation for this strange impoverishment of the rich Tertiary life, not only of Eurasia but of North and South America as well, seems to be the climatic changes consequent upon the long Glacial period. As the cold approached from the north many forms perished; others were driven south into Africa and the Oriental region, both of which they overran, their return being prevented in one case by the subsidence which left the Mediterranean sea, and in the other by the elevation of the Himalayan chain of mountains which cut off the Oriental region from Eurasia.

Eurasia has many forms of animal life in common with North America with which it seems to have been recently united by way of Alaska. The following are some of the types which originated in this region and sent emigrants to North America: bears, horses, tapirs, antelopes, elephants, and opossums. Besides these, many others such as wolves, beavers, and hares are similar in both regions. The only native animal received from North America is the camel, although the descendants of several other forms that originally went from this region to North America, passed back again in subsequent periods. Some Eurasian animals that do not occur in North America are hedgehogs, wild boars, and the chamois. Eurasia has many characteristic birds, numbers of which emigrate to the Oriental region to pass the winter season.

NORTH AMERICAN REGION. An examination of the fossil deposits of North America indicates a mammalian life during late Tertiary times almost as abundant as that which prevailed on the Eurasian continent. Many of these fossils are similar to Eurasian types, but occur in deposits a little more recent than those of that region whence they are believed to have come. Many unwieldy, generalized types became entirely extinct; the descendants of others are continuous right up to Pre-Glacial times. Lions, tigers, opossums, tapirs, camels, elephants, and horses were numerous. A curious phenomenon is the presence in Pliocene deposits (but not below them) of the remains of huge sloths and ant-eaters peculiar to South America, which seems to indicate that these animals made an extensive excursion into North America from the south during one of the periods when land-communication was established after long separation.

In North America, as in Eurasia, there is a remarkable dearth of certain great animal types at the present time, as compared with later Tertiary times. The cause is believed to be the same in both cases and is attributed to the effects of the Glacial epoch. Most of the present fauna of North America are descendants of those ancient types that from time to time came from Eurasia, either by way of Alaska, or from the east by way of Greenland. In addition to those already mentioned are deer, bison, swine, oxen, sheep, and goats. The earliest trace of the camel however is from North America, whence he passed into Eurasia and South America. The Canadian elk and the bison of the prairie probably correspond to the European elk and the Russian aurochs. The skunk, Rocky Mountain goat, musk-ox, gopher, tree-porcupine, and some others seem to be specially developed forms of the North American region.

ORIENTAL REGION. This region includes that part of Asia south of the Himalayan mountains, along with those islands in the Malayan archipelago north of "*Wallace's deep-sea line*," which forms the boundary between the Oriental and the Australian divisions. (It is certainly a most instructive illustration of the effect of a deep-sea barrier, that the twenty miles of sea between Bali

and Lombok should separate two faunas as distinct from each other as those of these two regions.)

Away back in Miocene time, before a great movement in the earth's crust had raised the Himalayan mountains and the extensive plateau of Thibet to their present elevations, an almost uniform climate extended over the whole of Europe and Asia, and, as shown by the nature of the fossils, it was characterized by substantially one fauna. Abundant remains of such forms as the elephant, the rhinoceros, and the tapir prove that it was also tropical. These conditions continued far into the Pliocene, when a gradual change, both physical and climatic, completely differentiated the Eurasian and Oriental faunas. The climatic change was from tropical heat to excessive cold. This alteration of climate was of course gradual, occupying probably thousands of years, and giving ample time for many animals to accommodate themselves to the new conditions, and it is the descendants of these modified forms which constitute the present Eurasian fauna. Others were driven far south, some into Africa, the remnant into South-Eastern Asia, where they gave rise to the *present fauna of the Oriental region*. The subsequent elevation of the Himalayas and the Thibetan plateau established a permanent barrier between the two regions.

Thus, we must look upon the Oriental and the African regions as presenting from a zoological standpoint, a fauna greatly reduced, but still similar to that of Europe and Asia in the Miocene epoch. The most characteristic mammalian animals are ourang-utans, long-armed apes, monkeys, and some strange species of lemurs. Some of the larger animals are wild cattle, tapirs, elephants, and rhinoceroses. The hippotamus and giraffe, though found in Africa, are absent from the Oriental region. This region is noted for its exquisitely colored birds.

DISTRIBUTION OF PLANT LIFE.

The distribution of plants, with a view to determining their original headquarters and subsequent migrations, has not been, up to the present time, very satisfactorily worked out. The means of dispersal possessed by many plants is much better than that possessed by most animals. The

effect of climate on plants is also usually much greater than on animals. The structure of herbaceous plants, too, is such that they are not well suited for preservation as fossils. Hence, for these and other reasons, the natural limits of botanical regions have not been so clearly marked out as those of zoological regions. At the same time something has been done in this direction by a number of noted workers, such as Bentham, Hooker, Drude, Gray, and others.

PLANTS.

Probably the most natural arrangement consists in recognizing three comparatively ancient and well-defined floras, each of which has several sub-divisions.

- I. Northern.
  1. Arctic-Alpine.
  2. Temperate.
  3. Mediterranean.
- II. Southern.
  1. Antarctic-Alpine.
  2. South African.
  3. Australian.
  4. Patagonian.
- III. Tropical.
  1. Indo-Malay.
  2. African.
  3. American.

I. NORTHERN FLORA. This division embraces most of Eurasia and North America, and its flora is one of the oldest and most extended. An examination of the fossil Tertiary flora of the region shows that the present plants are, as a whole, the direct descendants of those of Tertiary times, when an almost uniform flora extended over what was then a united circumpolar land mass, including the northern portions of both continents. Since that time certain groups, owing to distance and long isolation, have become more characteristic of North America than of Eurasia, while others are more numerous in Eurasia than in North America; but the general continuity of forms is so marked that the two regions must be considered together.

SUBDIVISIONS OF NORTHERN FLORA.

(1) *Arctic-Alpine Flora.* This flora is represented by small, hardy plants of slow growth, and is the characteristic flora of all Eurasia and North America, north of the temperate zone, and of all the principal mountain chains in the world. It is best represented in the Scandinavian peninsula, where it was probably preserved better than else-

where during the Glacial period. It extends down the Alleghany and Rocky mountain chains in North America, and along the Andes to the extreme south of South America. It is characteristic of the Pyrenees and the Alps in Europe, prevails on the mountains of tropical Asia and Africa, and in a less degree on those of New Zealand, Tasmania, and Australia.

The wide distribution of this flora, especially along elevated mountain chains, is accounted for as follows: At the close of the Tertiary period, the northern arctic land was covered with a vegetation continuous and identical over the whole region. As the glacial climate developed, this plant life began to move southward, and eventually reached, and even crossed, the equator. At the same time the Alpine plants were forced by the extreme cold to descend from the mountains into the plains, and thus to take part in the general migration southward. This resulted in a mingling of arctic and temperate vegetation in central Eurasia and North America. On the retreat of the ice a mixture of arctic and alpine plants followed close in the wake of the glaciers, and established themselves as far north as the climate would permit, thus constituting the present arctic flora. In a similar manner this same composite flora would follow the snow-line as it retreated to higher and higher altitudes up the mountain sides, and so would form the present alpine flora. We can thus understand why the species of plants that grow on the Alps and Pyrenees in Europe are also found on the Rockies and Alleghanies in North America. We can also understand why the alpine plants of the Pyrenees are allied to those of Norway, while those on the Alleghanies show a close relationship to those of Labrador.

Why northern forms should also extend to the Andes and other mountains of the southern hemisphere does not seem so clear. It is believed to be due to the northern plants having been developed through natural selection, to a higher degree of perfection than the southern forms. They occupied for a very long time an extended land area, where they were subjected to a keener competition and a greater diversity of environment, than those in the south, consequently towards the close of the Glacial period, when both northern and southern forms began their retreat from the equatorial regions, the northern forms became the dominant ones, and spread south as well as north.

In Norway and along some of the rivers of Russia and of Canada, forests, chiefly of pine and larch, reach as far north as latitude 70°, but, as a rule, the July isotherm of 50 marks the northern limit of forest growth. North of this only dwarf willows, birches, and low shrubs grow, along with grasses, mosses, lichens, and a few hardy flowering plants, like the saxifrage and arctic poppy.

(2) *Temperate Flora.* This consists of a very mixed vegetation of prolific and rapid growing herbs, shrubs, and

trees, with great powers of adaptation, and mostly of wide geographical range. The original headquarters of most of them seems to have been in Eurasia, though there have been large migrations into both Europe and Asia from America. To give a list of typical herbaceous plants of this region would be of little interest to anyone except the botanist. Some forest trees characteristic of the whole region are pine, birch, oak, beech, and poplar.

(3) *Mediterranean Flora.* The territory along the Mediterranean Sea on both sides possesses a rich and well-defined flora of its own, which has few points in common with either temperate or tropical areas. In Asia it is separated from the latter by the Himalayan mountains, and in Africa by the Sahara desert. Some characteristic types are olive, mulberry, chestnut, orange, cork-oak, and pine, with a number of low evergreen, and often thorny, shrubs, with leathery leaves, such as holly and laurel. The trees grow mostly in clumps, and not in extended forests.

II. SOUTHERN FLORA.

In the northern hemisphere, consolidated and extensive land areas permit of considerable continuity in the character of the vegetation. In the southern hemisphere, the land masses are quite isolated from one another by great bodies of water, consequently the vegetation of each, though possessing much in common with the rest, has a distinct individuality of its own. Thus we have Antarctic-Alpine, Australian, South African and Patagonian floras.

(1) *Antarctic-Alpine Flora.* This is the southern analogue of the arctic-alpine, and consists of a similar vegetation, mixed with some Australian representatives. These latter, and several others common to Australia and temperate South America, indicate a former antarctic land connection between these two continents, or, as Dr. A. R. Wallace insists, merely a communication by means of intervening islands, sufficient to allow of interchange of either animals or plants possessing considerable powers of dispersal.

(2) *Australian Flora.* The plant life of Australia, like its animal life, is a survival from the remote past. In their long isolation many species have become strangely modified to suit the arid climate of their insular home. In

some the leaves have become glossy and leathery, in others the flattened branches act as leaves, and still others turn their leaf-edges toward the sun. These devices prevent excessive evaporation of moisture. Myrtles, gum-trees (eucalyptus family), wattles (acacia family), and beef-trees (related to oak family), are characteristic. Some of the gum-trees grow to an enormous size; one felled near Melbourne measured 420 feet from the bottom to where the top was broken off, and at a point 300 feet from the ground it measured six feet in diameter.

(3) *South African Flora.* In proportion to its extent this is an exceedingly rich vegetation. It shows numerous affinities to that of Western Europe and the highlands of Eastern Africa, which would seem to indicate that South Africa received its flora, as well as its fauna, at a time when there was closer land connection with the northern continent than there is at present. Many of the world's garden flowers, such as pelargoniums, irises, lilies, and orchids, came originally from South Africa. Ironwood, and yellow wood are amongst its typical forest trees.

(4) *Patagonian Flora.* This includes the plant life of South America within the temperate zone. Some of its characteristic genera are fuchsia, calceolaria, and maté or Paraguay tea—a species of holly. In its forests are found trees similar to those of the north temperate zone, such as beech, oak, chili-pine, poplar, and willow. It also includes several species which are common to Australia, New Zealand, and Tasmania.

III. THE TROPICAL FLORA.

While the tropical floras of the various continents, as far as known, possess many features in common, they also present many striking contrasts. The great number of orders represented, and their richness in both genera and species, make the work of investigation and comparison a difficult one. The flora of tropical America is but imperfectly known, and even less has been ascertained regarding that of tropical Africa. Three great subdivisions are generally recognized—Indo-Malayan, African, and American.

(1) *Indo-Malayan Flora.* This is divided from the Eurasian temperate flora by the Himalayan mountains, and ex-

tends northward to Japan, and south to Wallace's line. It is the land of the teak, banyan, ebony, and sandalwood.

(2) *African Flora.* As far as this is known, it seems to consist of a great many ancient types, probably derived from Eurasia, as were the ancestors of its present fauna. Some of its characteristic trees are the oil-palm, baobab, and giant euphorbias.

(3) *American Flora.* No authoritative comparison of American tropical flora with that of Asia or Africa has ever been made. Several large orders and genera are known to be common to all three regions. Some of its most common types are cinchona, mahogany, rosewood, rubber tree, and cactus.

OCEAN LIFE.

The ocean has its life forms as well as the land. There are those that are always found near the shore; others that live on or near the surface of the ocean, far from land, but do not descend beyond a certain depth; and still others that are found only at great depths, and whose existence was not suspected until within the last thirty years. Hence, we speak of *Littoral*, *Pelagic*, and *Abyssal* life.

The chief barriers to distribution of aquatic life are *temperature* and *light*. Temperature divides shore forms, as it does land forms, into tropical, temperate, and arctic divisions. In the case of pelagic life, the boundaries of these divisions are greatly modified by warm and cold currents. In the deep sea there is little variation in temperature from arctic to antarctic waters, and hence nothing to prevent species from roaming at will. Beyond the so-called light limit, plants cannot grow. The light limit also forms an impassable barrier between the pelagic and the deep-sea fauna.

LITTORAL OR SHORE LIFE. This includes not only the plant and animal life of the shore, as popularly understood, but also that of a zone extending out into the water until a depth of about 200 feet is reached. Beyond this depth there is not sufficient light to permit of vigorous plant growth. Within this limit grow the beautiful rose-

colored corallines, and great strap-shaped brown and green seaweeds, the latter extending from the tropics to the poles, and becoming larger as they approach the colder latitudes. Nearer the shore are found glass-worts, and sea grasses of various kinds.

On account of the abundant food supply, the shore zone is exceedingly rich in representatives of all forms of animal life, from the protozoa to the mammals. There are free-swimming forms, some of which spend their whole life in one locality, others which venture far out to sea. There are crawling forms, that live amongst the rocks or that burrow in the sandy shore. Others attach themselves, some to seaweeds and some to rocks. Amongst the latter are sponges, oysters, barnacles, and the various rock-forming corals. Many delight in the surf, while others frequent the still waters of lagoons. The shallow waters form the great fishing grounds of the world.

PELAGIC LIFE. This includes all organisms, either swimming or drifting, that make their home in the open sea, and that do not descend to a greater depth than about 1,200 feet. Besides some corallines and floating sargassum, the only pelagic plants are unicellular algæ, which literally swarm in the surface waters of the ocean, and supply a great wealth of lower animal life with food. Their siliceous skeletons form an extensive deposit on the ocean floor.

Amongst pelagic animals are found representatives of almost all types, from microscopic protozoans to large forms like whales and porpoises, whose ancestors are believed to have been land animals. Many of the protozoans are provided with calcareous and siliceous skeletons, and so numerous are these forms that the sinking of their dead shells to the bottom of the ocean has been compared to the constant falling of snow. They constitute the white ooze which covers great areas of the sea floor.

Amongst pelagic forms are numerous jellyfishes, mollusks, crustaceans, fishes, turtles, snakes, birds, and mammals. Many of the lower forms multiply so rapidly that the ocean waters would soon become turbid, were it not that they constitute the main food supply of most of the larger animals. The surface of the sea is often lighted

up by shoals of these pelagic creatures, which have the power of becoming luminous in the dark. Many species which are on the surface at night retire into deeper water during the day.

ABYSSAL LIFE. Until the exploring expedition of *H. M. S. Challenger*, the deep sea was thought to be without life of any kind, but the results of that expedition and of others sent out since by both the British and the United States Governments, prove that while plant life is limited to the light line, an abundant animal life exists even in the deepest parts of the ocean. Representatives of every family, from protozoans to fishes, have been dredged up from various depths. Crustaceans occur mostly at depths less than 3,000 feet, but a large crab three feet broad was brought up by the dredge from a depth of 6,000 feet, and a blind species over two feet long, from water 12,000 feet deep. King crabs, the only living representatives of the very ancient trilobites, are found only in North American waters and in the Chinese sea. Protozoans with siliceous shells, siliceous sponges, solitary corals, crinoids, numerous shell-fish, worms, and ordinary fishes were hauled up from depths of from three to four miles.

Some of these deep water animals are degenerate representatives of well known shore and surface forms; others are survivals of ancient Secondary and Tertiary types, which, unequal to the struggle for existence with modern forms, have gradually retreated to their dark asylum, where the conditions of life are less exacting, where there is neither day nor night, summer nor winter, and where neither storm nor tide disturbs the stillness of the waters — a region of profound darkness, with unvarying conditions of environment. The inhabitants harmonize with the darkness, and are inky black in color.

At these great depths their bodies are subjected to enormous pressure — over two tons per square inch; the bones are feeble, and the soft flesh is held in place by the force of the water, so that, when a fish is brought to the surface its scales fall off, and its flesh becomes loose and porous, its eyes protrude, and its air-bladder is often forced out of its mouth, owing to the sudden decrease in outside

pressure. The looseness of the tissues enables some of these forms to distend their bodies so as to swallow animals much larger than themselves.

While abyssal animals prey to some extent upon one another, their chief food supply is derived from the pelagic forms whose dead bodies settle to the bottom. Since light cannot penetrate to these depths, the majority of deep sea animals are blind, or partially blind. Some, on the contrary, have abnormally developed eyes, probably to catch the feeble light given out by phosphorescent organs with which many of them are provided. In the absence of eyes, tactile organs are highly developed.

MAN.

Like each species of the lower animals, physical man may be regarded as a product of those conditions which have prevailed from time to time on the earth since life first appeared. He represents the highest type of development, resulting from those long-continued progressive changes which have always characterized living organisms in their unconscious efforts towards a higher existence. While still in a broad sense subject to the ordinary laws of heredity and environment, civilized man is, in a great measure, capable of creating, or at least of modifying, his environment, and of utilizing the forces of nature as his means of progress. There is practically no limit to his geographical distribution. His superior intelligence and high degree of adaptability enable him to contend successfully with the greatest extremes of climate and with the most adverse physical conditions. Man is distinguished from the lower animals by his habitually erect carriage, and by his great development of brain power, but his chief distinctive characteristic as a physical being is the possession of articulate speech.

PREHISTORIC MAN. Many remains and relics of prehistoric man have been found in almost all parts of the globe, including the northern and the southern hemispheres of both the old and the new world. These consist of skeletons, together with implements of various kinds, arrow-heads, hatchets, pestles, figures of animals, etc., associated with the remains of extinct mammals, such

as the cave bear, cave lion, and the mammoth. They date from the Glacial or the Post-Glacial epoch, and from their wide distribution show that Pleistocene man had already succeeded in occupying almost every part of the habitable globe. This age, in its relation to the history of prehistoric man, is known as the *stone age*.

The very earliest implements found are of the most primitive workmanship, roughly fashioned and unpolished; hence, this part of the stone age is termed the *Palæolithic* (old stone) age. Its beginning is of great antiquity, and some of the human remains, such as the famous Neanderthal skull, found in the Rhine valley, possess features somewhat Simian in character. According to Prof. Dana "The evidence seems to render it probable that the earliest prehistoric races, ranging from the East Indies to Western Europe, possessed features more Simian than are characteristic of any race of men now in existence."

Towards the close of the Palæolithic period the implements, though still unpolished, show an improvement in design and finish, affording evidence of a slight advance in culture. Drawings, on bone and ivory, of the reindeer, mammoth, and other animals now extinct, are numerous, proving that our ancestors of that time were familiar with these as living animals (Fig. 38).

NEOLITHIC AGE. In later deposits are found relics made of ground and polished stone, along with pieces of pottery, and bones of a few domestic animals, such as the dog, goat, and horse. This is known as the *Neolithic* age, and it is distinguished by a considerable advance in culture over the Palæolithic. The men of this age were familiar with the arts of spinning, weaving, and making pottery. They grew cereals for food, understood the uses of fire, and had succeeded in domesticating several wild animals. They had also made considerable progress in architecture, and many of their structures, such as burial mounds, stone galleries, and monoliths have withstood the ravages of time, and still excite the curiosity and astonishment of the modern world. These enduring monuments to the skill of our Neolithic ancestors are scattered far and wide, from Great Britain and France in

Western Eurasia, through North Africa to India and Japan in the east; and in the New World, from California and the Mississippi valley, through Mexico and Central America to Peru and Brazil in South America.

BRONZE AND IRON AGES. As Neolithic man acquired more complete control over fire, he gradually learned how to work the metals, especially bronze and copper, and eventually iron. The relics found in the curious Lake dwellings of various parts of Europe, but especially in those of Switzerland, show an almost imperceptible transition from the new Stone age to what is known as the *Bronze* age. Implements and ornaments made of bronze metal, and often showing considerable skill in workmanship, are found replacing those of stone,—usually in connection with tombs, temples, or other resting places of the dead. Mexico and South America also had their bronze age. In North America this period may be more fittingly termed the copper age. Deserted copper mines are frequently found at the present day, just as they might have appeared on being left by their prehistoric workmen at the end of a day's work. In one of these ancient mines near Lake Superior was found a mass of copper, some ten tons in weight, elevated on supports and ready for removal from the mine. There for thousands of years it had waited in vain for the return of these ancient workmen.

Bronze and copper implements and ornaments gradually gave place to those of iron, and thus we have the *iron age*, the early part of which belongs to the prehistoric period. As far as the most useful metal may designate a period, man may be said to still live in the iron age.

EARLY MIGRATIONS. Primitive man is believed to have originated in Eurasia, and from thence to have spread over the whole habitable globe. Judging from the similarity of the flint implements and crude works of art found in the different regions of the earth, the earliest inhabitants of these regions—the makers of these implements—must all have belonged to the same type of the human family. Many of the causes which led to their distribution were, no doubt, similar to those which operated in the diffusion of the lower animals. The degree of

intelligence possessed by the race at that period in its history must have been comparatively low, and it is altogether probable that man's earliest migrations were induced, in a great measure, without intelligent motive, but in obedience to the stress of prevailing conditions. His struggle for existence would involve contests with the many gigantic carnivorous animals of that period, but the keenest competition would probably be with those of his own kind. Owing to his superior intelligence, he would then, as now, dominate all other forms of creation. By dexterous use of his rude weapons he could compel the rest of the animal world to contribute in some degree to his needs; thus means of subsistence would never be entirely wanting, and only barriers of a very formidable character, such as the great oceans, would prevent his becoming the *only universal species*. That palæolithic man did, to a great extent, succeed in this, there is ample proof in the many evidences of his existence found in nearly all parts of the world. The elevation of the great land masses of the globe during early Pleistocene times shows how this wide distribution became possible. Europe, Asia, and Africa then formed one continuous continent, and America had land connection with Asia by way of Alaska and Siberia.

This dispersal into the different continents of the earth took place while man was yet a savage, in the lowest stages of human development, and capable of manufacturing only the rudest stone implements; it was a condition similar to that of the present natives of Australia, or the Bushmen of South Africa, whose civilization is still that of the stone age. His subsequent advancement and improvement must have proceeded in the several regions independently, as in the case of other animal varieties. In the Americas, Africa, and Australia, this development never advanced sufficiently to raise the inhabitants much above barbarism. Civilization and culture are the results of efforts and strivings which go beyond the supplying of mere present physical necessities. In order that a primitive race may make a permanent advance, their wants must be supplied from a diversity of sources, and thus give rise to varied forms of industry. The geographical features of their country must be such as to afford isolated regions,

provided with natural physical barriers, to protect them from incursions of less civilized races. Then those qualities which lead to advancement will be nurtured and matured, and successions of social life will be secured without interruption, for long periods of time. Only in this way can national motives be engendered and developed, and what we term civilization established.

The continent of Eurasia is in these particulars preeminently fitted to become the cradle of development of great races. It possesses in a marked degree those physiographical features alluded to, and which are noticeably absent from the other great land divisions of the globe.* In Eurasia alone has a primitive people ever been advanced through the several stages which lead up from savagery to civilization. Here the environment has been such as to call forth the highest activities of the individual and of the race. Here all the great civilizations of the world have had their origin, Egyptian, Babylonian, Assyrian, Persian, Indian, Chinese, Grecian, Roman, and European. Here also have been developed all the great languages and religions of the world.

Notwithstanding the pronounced altruism of the present age, it is probable that the struggle for existence, though somewhat disguised, is in the ultimate analysis, as keen and as uncompromising now, as it was in the days of our palæolithic ancestors. Almost every year thousands become the unfortunate victims of famine, while the more fortunate, or the more acquisitive, have enough and to spare. That only the fittest survive, also seems still true of the nation as of the individual. The native red man of America has been displaced by the more aggressive European; the aborigines of Tasmania have become extinct, and a like fate seems in store for the native black races.

CLASSIFICATION OF MANKIND.

If we place side by side an African negro, a Chinaman, an American Indian, and an Englishman, our first impression will be that each differs in a remarkable degree from all the others. When we try to discover wherein the differences lie, we shall be apt to attribute them chiefly to differences in color of the skin, in color and character of the hair, and in color and shape of the eyes. These differences are only superficial, and keeping in mind the distinctions on page 332, it

*See Shaler's Nature and Man in North America.

will be evident that all four must be placed in the same species, and that each one represents a variety. Natural selection working through heredity and environment has in time made them what they are.

Since Neolithic times man has no longer required land connection to enable him to overcome ocean barriers. The development of navigation and other methods of travel, have enabled him to spread at will over the different countries of the world. Thus, the different varieties of mankind have become intermingled in a very complex manner, and have given rise to numerous sub-varieties.

Prof. Keane groups all these sub-varieties around four principal types, as follows: The Ethiopian, or Black; the Mongolian, or Yellow; the American, or Red; and the Caucasian, or White; and this classification is the one most in favor at the present time. To the Ethiopian, or black variety, belong the least civilized of the human race. Their original habitat was Australasia and that part of Africa south of the Sahara desert. From the latter country they have since, against their will, spread to tropical America and the West Indies.

The Mongolian, or yellow type, includes more than one-third of the human family. The Thibetan plateau was probably their native home. They now occupy most of Asia, including Japan and Formosa, and have spread to parts of Europe, Australia, Madagascar, and America.

The so-called *red man* of America is, no doubt, derived from an Asiatic branch of the Mongolian type. His representatives once spread over the whole of the new world, but are now confined to unsettled regions and to certain *reserves* in North America, while in South America they are still partly in the tribal state, and partly amalgamated with Blacks and Europeans.

The Caucasian, or white variety of mankind, includes the most enlightened and progressive of the human race, and exceeds all the others in numbers. Their original home was in Africa, north of the Soudan, but they are now to be found in almost all parts of the world, and largely preponderate in Europe, America Australia, New Zealand, Egypt, and South Africa.

CHAPTER IX.

THE HEAVENS AS THEY APPEAR TO AN OBSERVER.

On whatever part of the earth's surface we happen to be, we see, on looking above us and around us, what appears like a great vault or dome, which we call the sky, curving down to meet the horizon on all sides. At night we see this dome studded with brilliant objects called stars, glittering in the heavens like innumerable arc lights. If

Fig. 154. Apparent diurnal rotation of Ursa Major.

we observe these carefully for some time we notice that while, as a rule, they keep their positions relative to one another, they may be seen gradually rising above the eastern horizon, passing across the sky, and then slowly sinking below the western horizon.

If we are in northern or southern latitudes it will be noticed, however, that some stars never sink below the horizon, but make a complete revolution about a fixed point in the heavens. If we are north of the equator and

direct our attention to that group of stars known as the Big Dipper, or Great Bear, (Ursa Major) it may be seen to move in a circular path around this fixed point, which is called the *north pole of the heavens*, and which is pretty closely marked out by a well-known star named Polaris, or the *north polar star*. Two of the seven stars composing this group or constellation are known as the "pointers," because they are always nearly in a line with the polar star, whatever the position of the constellation. In Fig. 154, this constellation is shown in four different positions, after intervals of six hours.

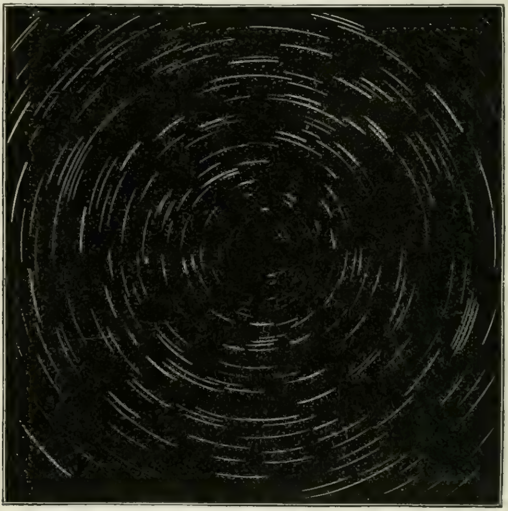


Fig. 155. Circumpolar star trails from a photograph.

All stars which move in parallel circles around the poles of the heavens are called *circumpolar* stars, indeed Polaris itself is one of these, as it describes a small circle with a radius of about 1·2 degrees around the true celestial pole. By exposing a photographic plate for an hour or two in a camera directed towards the north polar star, a print of the circular trails made by various stars as they pass over the plate in their apparent rotation may be obtained. One of these is shown in Fig. 155.

A little farther from the pole each star in its circular path sinks below the horizon, and is lost to view for a time, and the farther the star is removed from this point the longer it remains invisible. Stars that are 90 degrees away will complete one-half of their revolution above the horizon, and one-half below the horizon. The sun and the moon, also join in this great diurnal rotation.

Apart from this daily rotation the vast majority of the bodies in the heavens have no other motion with which we need concern ourselves at present. As the constellations appeared to the ancients so they appear to us to-day. The individual stars send out their shafts of light at sensibly the same angles as when Ptolemy speculated concerning them in the early days of astronomy. In fact it is just as if the sky were a great rotating crystal shell of which the observer occupies the centre, and the stars were so many brilliants firmly set in it and moving with it. Now all of these celestial objects which form the constellations, and which constantly keep the same positions with respect to one another, are known as *fixed stars*, and they constitute by far the greatest number of those brilliant points of light seen in the starry heavens.

But besides the fixed stars and the sun and the moon, there are about half a dozen other celestial bodies which to the naked eye present an appearance very similar to that of the fixed stars. If these are watched carefully night after night, it will be seen that while they rise and set daily, they do not always keep the same positions among the other stars; that while the fixed stars have not changed their relative positions throughout the centuries, these in the course of a few hours assume entirely new positions through an independent motion of their own. These bodies, on account of their having other motions besides their apparent diurnal one, were called by the ancients *planets*, or wanderers. Five of them, Mercury, Venus, Mars, Jupiter and Saturn have been known from very early times.

Besides their more complex movements the planets can be distinguished from the fixed stars by their greater brilliancy, and also by their increase in size, when observed through a telescope. A planet like Jupiter or Saturn,

when viewed through a good telescope, becomes a very conspicuous object, while the fixed stars remain mere points of light, even when seen through the most powerful instruments.

The sun and the moon, besides their daily apparent motions, have also other apparent motions of their own amongst the fixed stars; but the fixed stars do not take part in these additional movements of the sun and planets, and their apparent rotation, as will be proved later on, is due to the real rotation of the earth on its axis. The effects are the same however, whether we attribute the daily movement to the star-dome, or whether we conceive of it as confined to the earth, and it is often convenient to speak of the apparent motion of a celestial body as if it were the real motion.

MAGNITUDE OF STARS.

"One star differeth from another star in glory." The total number of stars visible to the naked eye is about 6,000, that is, about 3,000 in each hemisphere. Some of these are much brighter than others. Twenty of the brightest are called stars of the first magnitude. Of these, Sirius outshines all others. Polaris is a star of the second magnitude, of which there are about 65. In this way they are graded up to fourteenth, and even to sixteenth and seventeenth magnitudes. The unaided eye cannot detect stars beyond the sixth magnitude, but the telescope reveals the existence of at least 50,000,000 stars, and modern photography has almost doubled that number. Generally speaking, the difference in brilliancy is believed to be on account of difference in distance rather than in size.

DISTANCE OF STARS.

The fixed stars are at such infinite distances from us that the ordinary units of measurement fail to convey any impression to the mind. We think of the sun as being at an immense distance from the earth. Light takes about eight *minutes* to reach us from the sun but from the average star of the first magnitude light requires over fifty *years* to travel to the earth. The time required increases with the decrease of magnitude, until in the case of a star of the twelfth magnitude, the vibrations, though travelling with lightning speed, would occupy 2,400 years in traversing the enormous expanse of space separat-

ing it from the earth. We see Sirius by the light which left that star over eight years ago, and the light waves which are now arriving from Polaris set out on their journey to our planet more than thirty years ago. If every star that shines so brightly in the firmament should suddenly become a cold, lifeless thing, we should not be aware of the fact, as far as our sense of sight is concerned, for years, and in many cases centuries to come.

STARS AS SUNS. The conclusion arrived at by the use of the spectroscope is that stars are suns in various stages of evolution, some of them in their formative condensing stage, with a gradually increasing temperature, others intensely hot with a photosphere similar to our sun, others again that have long since passed the period of their maximum temperature and are gradually contracting and cooling down. Many may have cooled to such an extent that they have ceased to give out light. It may be supposed that those that have reached the stage arrived at by our sun are accompanied by planetary systems similar to ours, but their distances are so great that even if these supposed planets were many times the size of Jupiter, our most powerful telescopes would fail to detect them.

The name "fixed star" would seem to imply that these bodies have no motion of their own. Now, while they have no such motions as the planets have, and appear to the naked eye to occupy the same relative places as they did a thousand years ago, yet it has been ascertained, that after long intervals of time, most stars show a slight change in position relative to other stars near them. This is termed their "proper motion" to distinguish it from their apparent motion. Our sun is no exception to the rule, but accompanied by his whole family of planets, is rushing through space with tremendous velocity towards the constellation Hercules. In addition to their proper motion it has been proved by the spectroscope that many stars have a motion in the line of sight, some approaching our system, while others are receding from it. Each of these motions is probably a component part of an orbital motion.

We must therefore regard the sun and moon and the planets as next door neighbors to our earth, which is itself a planet, the whole forming what we call the solar system. This system is completely isolated in space, so much so indeed as probably not to be affected in the slightest degree by any other body or system in the universe.

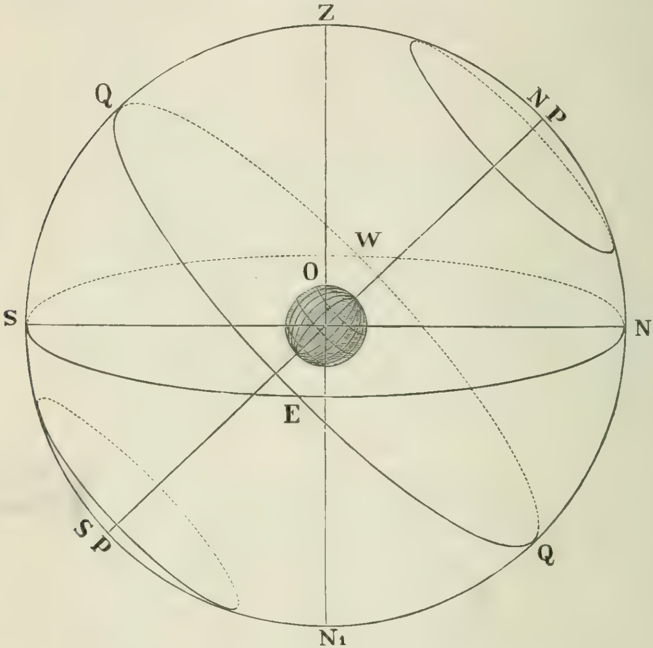


Fig. 156. The celestial sphere at the latitude of Toronto.

THE CELESTIAL SPHERE. All of the heavenly bodies appear to be situated on the celestial sphere, and just as we require certain imaginary lines on the terrestrial globe by which to locate places on its surface, so we require certain circles and reference lines to define the positions of objects on the celestial sphere. If we conceive of the earth as being inflated like a great foot ball, until it touches the sky, and each imaginary circle on its

surface as leaving an imaginary impress there, it will make clear what is meant by saying that each circle on the earth has a corresponding circle in the heavens.

In Fig. 156, let O represent the earth, which must be considered as a mere point in comparison with the celestial sphere. Its axis extended represents the *axis* of the celestial sphere terminating in the *celestial poles* N P and S P. The circle E S W N indicates the plane of the *rational horizon*, which always passes through the centre of the earth. The point Z directly over the observer's head is the *zenith* and the corresponding point N_1 in the opposite hemisphere is the *nadir*. The great circle Q E Q is the *celestial equator*. It is the plane of the earth's equator extended to meet the heavens. The small circles parallel to the equator correspond to parallels of latitude on the earth, and corresponding to the meridian of the terrestrial sphere, there are the *hour circles* of the celestial sphere. The hour circle S Z N N_1 which passes through the zenith and the poles, and which cuts the horizon at the north and south points, is *the meridian*.

ALTITUDE, AZIMUTH. One way of locating an object on the star-sphere is to fix its position with reference to the horizon. To do this we ascertain its distance in degrees above the horizon, or its *altitude*, and also its distance east or west of the meridian which passes through the south point of the horizon or its *azimuth*. A star due south has an azimuth of 0°, one due west an azimuth of 90°.

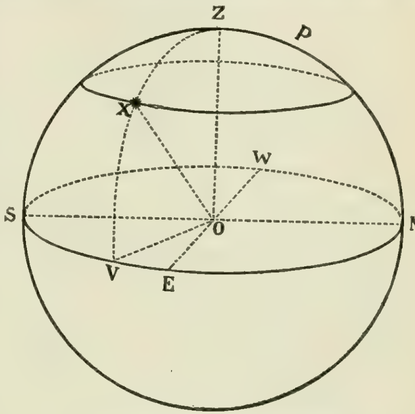


Fig. 157. Altitude and Azimuth.

In Fig. 157, E S W N represents the plane of the horizon as it appears to an observer at O. The altitude of the star at X would be the number of degrees in the arc V X, or in the angle V O X. Its azimuth would be the number of degrees in the arc S V or the angle S O V. Azimuth may be reckoned either east or west of south. All stars on the vertical circle V X Z have the same azimuth, and all stars on the same circle as X, parallel to the plane of the horizon E S W N, have the same altitude.

Since the azimuth and altitude of a star change as the observer's position changes, and since they also vary with the time at which the

observations are made, another method of defining the position of an object in the heavens is generally employed, which is free from these objections.

DECLINATION AND RIGHT ASCENSION. The position of a celestial object may be fixed by reference to the celestial equator instead of to the horizon. This method corresponds exactly to that of finding the latitude and longitude of a place on the earth's surface; hence, *declination* means angular distance from the celestial equator. North of the equator is positive (+) and south of the equator negative (−). As represented in Fig. 158, the sun's path in the heavens, called the *ecliptic*, intersects the celestial equator in two places. One at V, where the sun crosses the equator in spring, which is called the *Vernal Equinox* (or *first point of Aries*), and the other at A, called the *Autumnal Equinox* (or *first point of Libra*). The vernal equinox is the starting point on the celestial equator for reckoning right ascension(R.A.), and is called 0 (hours), just as in the case of the earth, the meridian that passes through Greenwich, and that is the starting point for estimating longitude, is called 0 (°degrees). Right Ascension of a heavenly body is always reckoned from *west towards east* along the celestial equator, and instead of being expressed in degrees is expressed in hours, minutes, and seconds. In Fig. 158, the arc M X, or the angle M O X, represents the declination of the star X, while the arc V M, or the angle V O M, represents its R.A. Ninety degrees, minus the declination, will give the *polar distance* X, NP.

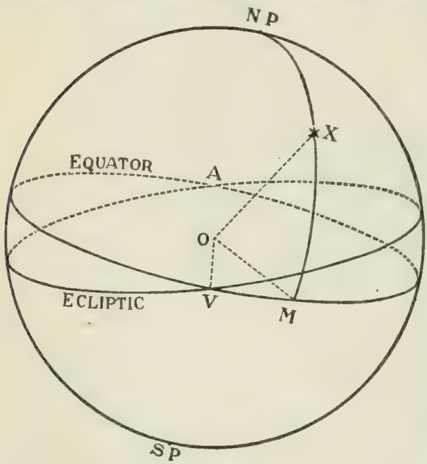


Fig. 158. Declination and Right Ascension.

THE SOLAR SYSTEM.

The solar system consists of (1) the sun, which is one of the stars of the celestial sphere, a white, hot, light-giving body, which appears much larger than the other stars, because it is much nearer; (2) eight primary planets, named from the sun outwards—Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. Each of these planets, except Mercury and Venus, has one or more secondary planets, called satellites or moons, revolving around it, and accompanying it in its revolution around the sun; (3) four or five hundred smaller planets invisible to the naked eye, whose orbits lie between those of Mars and Jupiter; (4) a great number of comets with extremely elongated orbits; (5) myriads of meteors, bodies usually associated with comets and moving in similar orbits.

THE PLANETS. These are opaque, globular bodies, each of which describes an elliptical orbit around the sun, which is situated in one of the foci, and this focus is common to all the orbits. When nearest the sun a planet is said to be in *perihelion*, and when in that part of its orbit farthest from the sun it is in *aphelion*. They all perform their revolutions about the sun in one direction, and they also rotate on their axes in this same direction. The planes of their orbits almost coincide with the plane of the earth's orbit; thus their movements seem to be performed near the ecliptic, which is the meeting place of the plane of the earth's orbit with the sky. In fact, the planes of revolution of the visible planets are all confined to a narrow highway called the *Zodiac*, extending about eight degrees on each side of the ecliptic, which may be regarded as a beaten path in the middle of the Zodiac. There are 12 constellations, which lie at intervals of about 30°, along this belt in the heavens (Fig. 159), and the name Zodiac was applied to it from a fancied resemblance these groups of stars bear to certain animals.

As far as known, the planets in their *orbits* perform their revolutions with their axes all inclined more or less from the perpendicular. In the case of Saturn the inclination is 28°, somewhat greater than that of the earth. Jupiter's axis, on the other hand, has an inclination of only three degrees from the vertical.

Roughly speaking, each planet is about double the distance of the preceding one from the sun. Those nearest the sun move in their orbits with the greatest velocity, while, as a rule, those most distant from the sun rotate most rapidly on their axes.

IMAGINARY VIEW OF SOLAR SYSTEM.

A tolerably clear notion of the arrangement of the various members of the solar system may be obtained by supposing the surface of a sea of smooth water to represent the plane of the ecliptic. In the middle of this sea is a stationary buoy to represent the position of the sun.

Half immersed in the water, as are all the planets in this imaginary system, and gliding swiftly around the sun with a radius of two yards, and at the same time spinning on its axis, which is inclined about 20 degrees from the perpendicular, is a globe about one foot in diameter. This is the planet Mercury.

Sailing almost at the same rate, in another circle about two yards outside of this one, is a nearly upright rotating sphere $2\frac{1}{2}$ feet in diameter, representing the planet Venus.

Next comes our planet, the Earth, represented by a globe about the same size as that of Venus. It spins about on an axis $23\frac{1}{2}$ degrees out of the perpendicular and describes a circle with a radius of five yards from the sun.

At an interval of three yards from the earth's path, and with a little less velocity, is seen Mars turning on an inclined axis and represented by a globe $1\frac{1}{2}$ feet in diameter.

About six yards outside of the circle in which Mars sails around the sun, we may imagine four or five hundred small spinning bodies about the size of marbles floating in their respective orbits at various rates. These are the Asteroids.

Next in order, moving almost upright in a circle with a radius of nearly 30 yards from the sun, and about 15 yards from the orbits of the asteroids, appears the majestic Jupiter. He moves through the water with less than half the velocity of the earth-globe, but turns on his axis with tremendous speed, and is represented by a sphere 28 feet in diameter.

With slower motion still comes the planet Saturn, which we may represent as a sphere 25 feet in diameter. Spinning rapidly on its axis it describes a circle in our imaginary sea 20 yards from the orbit of Jupiter.

Forty-eight yards outside of the last circle, still another globe moves leisurely around the sun. It is 10 feet in diameter and marks out an orbit for the planet Uranus.

Outside of all these circles, (really ellipses), 55 yards beyond the path of Uranus and 150 from the sun, bringing up the rear of this grand procession of worlds, revolves a globe 12 feet in diameter—the slow-sailing Neptune, which requires 165 years to perform its real journey around the sun.

It would complicate our illustration too much to do more than merely mention the secondary planets—the satellites or moons, which perform their revolutions about the primary planets after the same fashion that the primary planets revolve about the sun. Of these the earth has one, Mars two, Jupiter five, Saturn nine, Uranus four, and Neptune one. On the above scale our moon would be represented by a globe about 9 inches in diameter, while the largest of Jupiter's satellites, and also the largest of Saturn's, would measure about one foot each in diameter.

In order to keep this imaginary picture of the Solar system a reasonable size, the planets' distances have been expressed in yards. If instead of yards we read miles, and if instead of a point to represent the sun we substitute a globe with a diameter of 290 feet, the sizes of the various bodies and their distances apart will be reduced to the same scale. The planes of the planets' orbits have all been considered as in the plane of the ecliptic—in this case the surface of the water. So nearly is this true that the swell of the sea would produce sufficient difference of level to give the plane of any planet's orbit, for the moment, the proper inclination to the plane of the ecliptic.

Let us next consider the positions of the stars with respect to the solar system.

Using the proper scale of distances, where, in our imaginary sea, shall we place the nearest star? Will it be possible to find a sea large enough to give it a place? If it

were as large as Lake Superior it would not extend far enough. If our imaginary sea were the Atlantic Ocean, its bounds would still be too narrow. Indeed, since it must be placed at least half a million miles away, we can find no place for the nearest fixed star, even if we suppose our sea to cover the surface of the whole earth.

This serves to bring clearly before us the complete isolation in space of the solar system. "The sun surrounded by its orderly family of planets and an irregular host of attendant comets and meteors is practically alone in the centre of the star sphere, forming one system isolated by inconceivable expanses of space from the fixed stars."

KEPLER'S LAWS. From a careful examination of the records of observations of the relative positions of the sun and planets, a Danish Astronomer, named Kepler, deduced the following laws.

1. Each planet in its motion describes an ellipse, in one focus of which the sun is situated.

2. The radius vector, or straight line joining the centre of the sun and the centre of a planet, traces out equal areas in equal times. Fig. 116.

3. The squares of the periodic times of the planets have the same ratio as the cubes of the mean distances of the planets from the sun.

From the second of these laws Newton deduced the fact that the force which causes a planet to move in its elliptic orbit, must always act in the direction of the line drawn from the planet to the sun. Then from the first law he showed that this force must vary inversely as the square of the distance of the planet from the sun. From the third law he was able to show that the forces acting on the different planets produced effects that varied only because of the different distances of the planets from the sun.

Newton knew that a body, allowed to fall freely at the earth's surface, was drawn towards the centre of the earth 16·1 feet in the first second of its fall, and that a projectile was deflected from its path at any instant by the same amount. When he examined the moon's motion he found that it fell away towards the earth's centre from its direction of motion at any instant $16 \cdot 1 \div 60^2$ feet in a second. Remembering that the moon's distance from the earth was nearly sixty times the radius of the earth, Newton inferred that the moon's motion, in an ellipse, about the earth in one focus, was due to the attraction of the earth. From the consideration of these planetary motions, Newton was led to the statement of the law of universal gravitation: "Every

particle of matter in the universe attracts every other particle by a force which acts in a line joining the particles, and which may be measured by the product of their masses divided by the square of the distance between them."

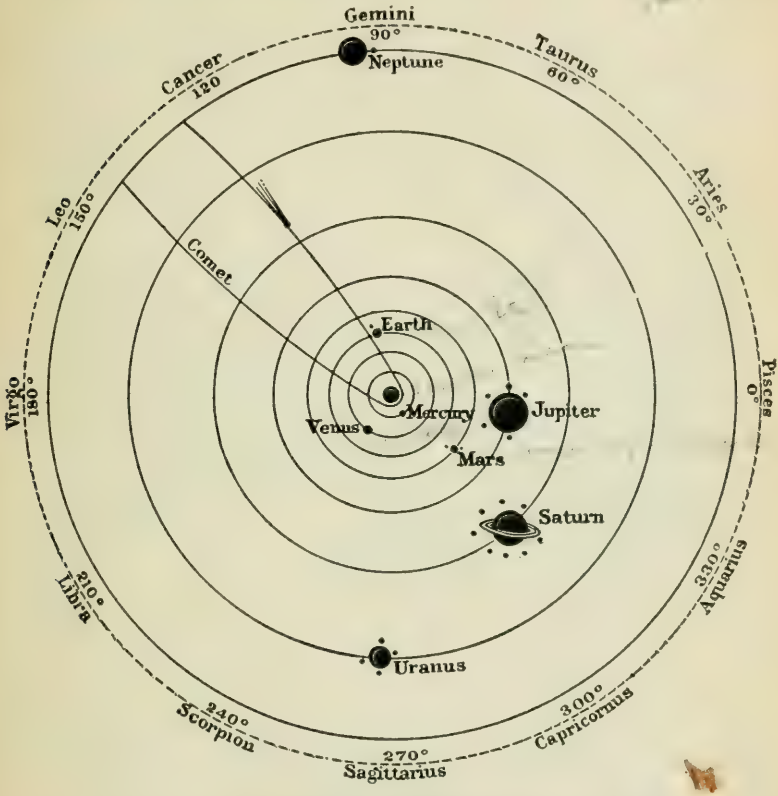


Fig. 159. Relative directions of planets from the sun, Jan. 1st, 1904.

The outer circle represents the Zodiac; the inner circles the orbits of the different planets, etc.

Assuming the truth of this law, mathematicians are able not only to explain the apparent planetary motions, but also to predict the positions of the planets at any future time.

THE EARTH AS A PLANET.

As the earth is one of the planets, and that one with which we are most concerned, we shall study it somewhat in detail.

SHAPE OF THE EARTH. The earth is approximately a sphere. The proofs of this are familiar to every school boy. A few of these may be given.

1. If any portion of the earth be viewed from a position above the sea level the horizon is always a circle, and the more elevated the position, the greater the radius of the circle. From 6 feet above sea-level the radius is 3 miles. From 3000 feet it is 70 miles and from 20,000 feet it is nearly 180 miles. This is characteristic of a sphere only.

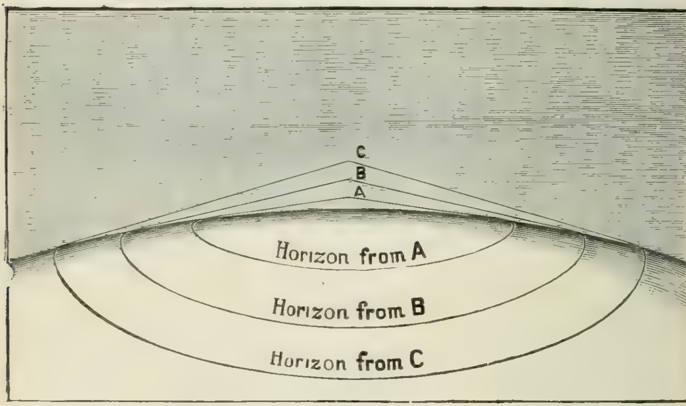


Fig. 160. Only a sphere gives a circular horizon.

2. The shadow of the earth seen on the moon's surface during an eclipse is always circular, no matter in what position the earth may be with regard to the sun, Fig. 176. Only a sphere could cast such a shadow.

3. The times of rising and setting of the sun are different at places situated on different meridians. If the earth were a plane the sun would rise and set at the same time for every person on its surface. This is not the case. When it is noon in England the sun is rising to the people of Ontario and setting to those of India.

4. To the observer at the equator the north polar star appears on the horizon; as he travels northward its altitude continually increases until at the pole the star would be in his zenith. If the earth were flat the altitude of the star would be the same from all points on its surface.

5. The earth has been travelled around in various directions. This, and the fact that a vessel going out to sea gradually disappears from view, and one approaching port comes gradually into view, also prove that the earth is round.

THE EARTH NOT A PERFECT SPHERE. As has already been stated, the earth is only approximately a sphere. It is usually classed as an *oblate spheroid*, being flattened slightly at the poles and bulged out at the equator, but as the result of very accurate measurements of the force of gravity by means of the pendulum and the spring balance, a difference of from one to two miles has been found in the earth's equatorial diameters. Hence it is not a true oblate spheroid, and the term *geoid* has been coined to apply to its irregular shape. If it were a perfect sphere, degrees of latitude would be of the same length on all parts of its surface, but this is not the case. If we travel north or south along a meridian until we have made a difference of one degree in the altitude of the celestial pole, we shall then have travelled over the distance of one degree on the earth's surface. But it has been found that this distance is not always the same; as we approach the poles it becomes greater. For example, in Peru the length of a degree is about 363,000 feet, while in the north of Sweden, it measures 366,000 feet. A degree near the poles must

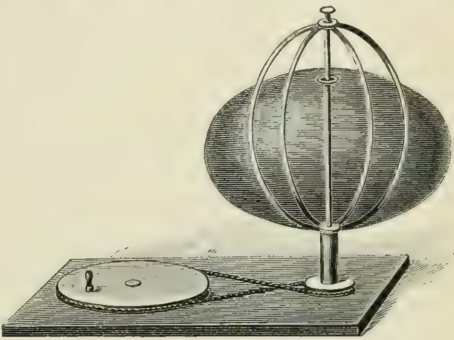


Fig. 161. Effect of rotation on a plastic body.

therefore be part of an arc of a greater circle than a degree near the equator.

If the earth be flattened at the poles and bulged out at the equator, then the force of gravity should increase as we approach the poles, and decrease as we travel towards the equator. This is found to be true, and after allowing for the difference in the influence of centrifugal force, a body is found to weigh more near the arctic circle than at the equator. At the equator a degree of latitude measures 68·69 miles, while near the pole a degree measures 69·38 miles, the average length being about 69 miles. If we multiply this by 360 we find the earth's circumference to be 24,840 miles. This divided by $3\frac{1}{7}$ gives the diameter as 7918 miles. The polar diameter is really 7899·6 miles, and the equatorial 7926·6 miles, making a difference of 27 miles.

The ellipsoidal form which the earth has, would result from a rapid rotary motion about its axis when in a plastic state, and is fully accounted for by the nebular theory. A circular figure made of elastic hoops of steel joined at the top and bottom to rings free to move on an upright rod, may be made to assume the shape of an oblate spheroid by being rapidly rotated on a whirling table as shown in Fig. 161.

LINES OF REFERENCE. In order to locate places on the earth we imagine certain lines and points to be marked on its surface, the lines taking the form of circles. The earth rotates about its shortest diameter which is known as its *axis*. The ends of the axis are the north and south poles. All places equally distant from the two poles are on a great circle called the *equator*. Circles on each side of the equator, and parallel to it, are *parallels of latitude*. These become smaller and smaller as they approach the poles, until those which pass through the poles are so small as to be mere points. The longest parallel of latitude is the equator, and on maps this is marked 0°, and those through the poles are marked 90°.

If we know the parallel of latitude upon which a place is situated, we know how many degrees it is north or south of the equator, but in order to define the particular part of the parallel it is on, we must have circles running at right angles to the lines of latitude. These are called lines of *longitude*, or *meridians*. They all pass completely around the earth through the north and south poles. At the moment any one of these lines passes the sun, as the earth rotates, it is midday at all places situated on that meridian, and midnight at all places correspondingly situated on the opposite side of the globe.

Just as latitude is reckoned in degrees north or south of the equator, so longitude is reckoned in degrees east or west of a certain

meridian, called the *first meridian*. Any country may have its own first meridian. The first meridian for the whole British Empire is the line of longitude which passes through Greenwich, England. This, on maps, is marked 0°, and places east or west of this are so many degrees east or west longitude. The degrees number from 0 to 180 in both directions. Degrees of latitude may be taken as all of the same length, about 69 miles, but degrees of longitude become shorter as they approach the poles, where they become zero. A degree of longitude at the equator is about 69 miles. At the latitude of Toronto a degree of longitude is only 50.114 miles. The greatest latitude a place can have is 9 ?; the greatest longitude 180°.

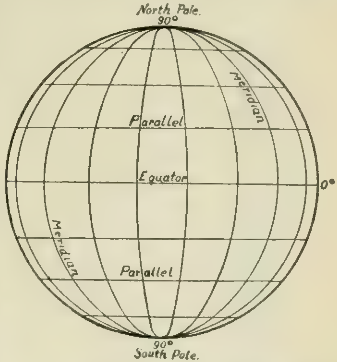


Fig. 162. Imaginary lines on the earth's surface.

ROTATION OF THE EARTH. The rising of the sun and the stars in the east, and their setting in the west, and the daily motion of the circumpolar stars, can be explained in two ways: either all of these bodies, scattered in different directions over the heavens at varying distances from the earth, move around in unison, and, notwithstanding their different distances, in the same time, (24 hours); or these bodies are stationary in their different positions in the celestial sphere, and the earth rotates in a direction opposite to that in which they seem to move; that is, the earth must turn from west to east.

There are many reasons for believing that the latter is the true explanation. A rotation of the earth on its axis, when in a plastic state, will explain why the equatorial diameter of the earth is greater than the polar diameter. The rest of the planets, when viewed through a telescope, are found to be spherical, and to revolve on their axes. Besides these reasons for believing in the rotation of the earth, there are several experimental proofs of such a movement, two of which may be mentioned:

1. If the earth turns from west to east, then the top of a high vertical tower must move sensibly faster than the bottom, and a weight dropped from the top, starting with

a greater eastward velocity than that possessed by the base of the tower, should fall a little east of a perpendicular from

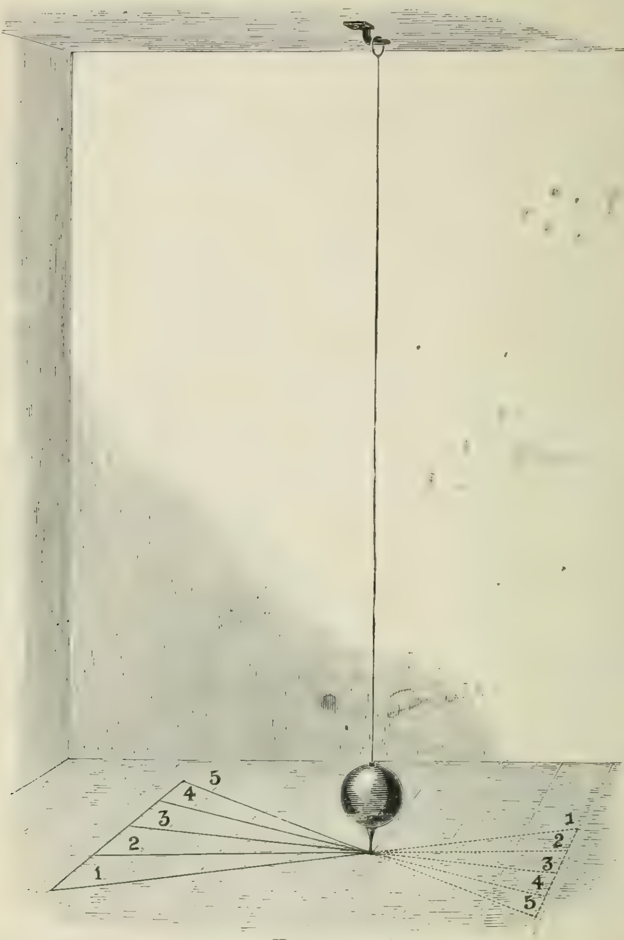


Fig. 163. Foucault's experiment to prove the rotation of the earth.

the top to the base. That it does so has been verified by experiments made in different places.

2. What is known as *Foucault's experiment, Fig. 163, renders the earth's rotation visible. If a heavy weight be suspended from a support by a long fine wire, and then set swinging backwards and forwards like a pendulum, it will continue to swing in an invariable line, even if the support to which the wire is attached be moved through a complete circle, as it is easier for the wire to twist than for the heavy pendulum to change its line of movement. This experiment was first performed by Foucault at Paris in 1851. His pendulum was suspended from the dome of the Pantheon, and was set swinging by burning the thread which attached it to the wall. At each swing a mark was left in some fine sand by a style at the bottom of the pendulum. Had the earth been at rest but one mark would have been made ; in reality, a succession of marks was made in the sand, which showed that the plane of its swing changed slowly and regularly with regard to the building, and the only way in which this could be brought about was by a rotation of the building and the earth upon which it was situated. The velocity of the earth's surface due to rotation increases from 0 at the poles, to 500 miles an hour at parallel 60°, and over 1000 miles an hour at the equator.

SOME EFFECTS OF THE EARTH'S ROTATION.

Having shown that the earth turns on its axis once a day, we shall next consider some of the results of this diurnal movement. One result has already been alluded to, namely, the apparent motion of all the heavenly bodies, sun, moon, and stars, around the imaginary axis of the celestial sphere, so that to an observer at the north pole the stars in one half of the heavens would appear to move around in circles parallel to his horizon. At the equator all the stars would seem to describe vertical semi-circles, rising in the east and setting in the west. To the observer in middle latitudes some stars would never set, some would rise and set, and some would perform their apparent daily rotation invisible to him. Another very important effect of the daily rotation of the earth is the *recurrence of day and night*. The earth is a dark non-luminous body, depending for its light almost entirely on the sun, which sends out its rays in all directions. The half of the earth turned toward the sun will always be lighted up, while the half turned away from the sun will be in darkness. If the earth were at rest, the one hemisphere would thus be in perpetual sunlight and the other in perpetual darkness ; but since the earth is continuously turning on its axis, in one rotation each

*This experiment was repeated in 1902 at the same place as Foucault performed his original experiment.

hemisphere in turn receives the sunlight and passes on into the darkness. Thus we have day and night.

REVOLUTION OF THE EARTH ABOUT THE SUN. Besides the apparent daily motion of the sun and stars, the sun appears to move eastward among the fixed stars nearly a degree every day, and thus in the course of a year to complete a great circle in the heavens. If on any clear evening, just after sunset, we notice a fixed star near the horizon to the east of where the sun disappeared, on the next evening, at the same time, it will be seen nearer to the place where the sun set, and on the next still nearer, and so on until it sets before the sun. Or if, by means of a telescope, the sun and a fixed star be seen in conjunction at a certain hour, 24 hours later the sun will appear to have moved a degree to the east of the star; in 24 hours more it will be two degrees to the east, and so on, until in the course of a year, after making a complete circuit of the heavens, it will again be in a line with the same fixed star. This apparent change of the sun's position can be explained by supposing that the sun has an annual motion around the earth from west to east among the fixed stars. But the effects of this apparent yearly motion of the sun around the earth would be the same if we supposed the earth to move around the sun, and since the sun is more than a million times the size of the earth it would seem more reasonable that the smaller body should move around the larger one than that the larger should move around the smaller. And just as there are proofs that the daily rotation of the sun and stars is only apparent, while that of the earth is real, so there are proofs that the eastward yearly motion of the sun around the earth is only apparent, and that the real motion is that of the earth around the sun. (These proofs may be found in almost any work on astronomy.)

ORBIT OF THE EARTH. Besides its daily rotation on its axis, then, the earth travels around the sun once a year, in one plane, on a fixed path called its orbit. This orbit is almost, but not quite, a circle. It is, as has been stated, an ellipse, a sort of flattened circle. If a pin be fixed in a piece of paper, and a loop of thread passed

over it, and a pencil placed in the other end of the loop, a figure may be described which will be a circle. Now if instead of one pin, two be fixed in the paper, the figure described will be an ellipse, and the pins will be at the two foci. Fig. 164 illustrates the method of describing an ellipse. The pins are at the foci. The closer the foci are to each other, the nearer the ellipse will approximate a circle. In the case of the earth's orbit the foci are comparatively close together, and hence the orbit of the earth, if represented on a true scale on one of these pages, could not be distinguished by the eye from a circle. Every planet

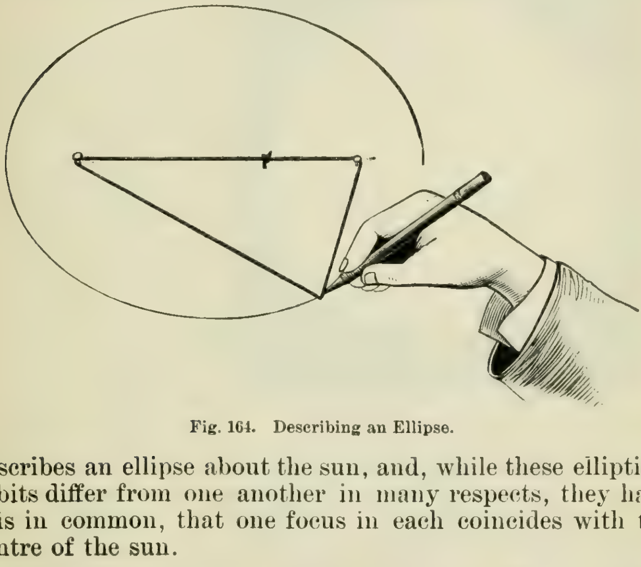


Fig. 164. Describing an Ellipse.

describes an ellipse about the sun, and, while these elliptical orbits differ from one another in many respects, they have this in common, that one focus in each coincides with the centre of the sun.

Since then the sun occupies one focus of the earth's orbit, the earth must be nearer the sun at certain times than at others. When nearest the sun, the earth is said to be in perihelion, when farthest away in aphelion. The earth is in perihelion on January 1st, and in aphelion on July 1st. For this reason the sun appears larger in midwinter than in midsummer. Fig. 165 shows this apparent difference. It is possible to construct the earth's orbit by making

careful measurement of the sun's diameter at frequent intervals. The resulting figure is an ellipse, with the sun in one of the foci.

VARYING VELOCITY OF THE EARTH. There is considerable difference in the velocity with which the earth moves in different parts of its journey around the sun. It has its greatest velocity when in perihelion, and its least when in aphelion. Newton has shown that this effect follows from the action of gravity, and Kepler's second law states that the *radius vector*, or line joining the centres of the earth and sun, sweeps through equal areas in equal times. In Fig. 166, S A, S B, S C and S D, represent different positions of the earth's radius vector, as it sweeps through space, and the area S A B is equal to the area SCD. and these have been described in equal times; therefore the earth must have travelled through the long arc A B in perihelion in the same time that it passed over the short arc C D in aphelion.

Fig. 165. White disk inside dark circle shows the sun, July 1st; the whole, the sun Jan. 1st.

As a matter of fact, the earth travels from the autumnal to the vernal equinox in 179 days, while it occupies 186 days in going from the vernal equinox to the autumnal. From its maximum velocity at perihelion, the decrease is gradual, until the minimum is reached at aphelion, after which there is a gradual increase until the maximum is again reached at perihelion. The average velocity of the earth in its revolution around the sun is about 18½ miles per second.

THE ECLIPTIC. The intersection of the plane of the earth's orbit with the sky is called the ecliptic. (See Fig. 158). The sun appears to move along the ecliptic, because, as the earth moves in its orbit, the sun is always seen projected on the opposite side of it. The plane

of the ecliptic at all times passes through the centre of the sun and the centre of the earth.

INCLINATION OF THE EARTH'S AXIS. Instead of the earth moving around in its orbit with its axis upright, the earth's axis is always inclined to the plane of the ecliptic at an angle of $66\frac{1}{2}$ degrees, and it follows from this that the plane of the earth's equator makes an angle of $23\frac{1}{2}$ degrees with the plane of the ecliptic, that is, the earth's axis is $23\frac{1}{2}$ degrees out of the perpendicular during the entire revolution. Not only is this the case, but the directions of the axis in the various

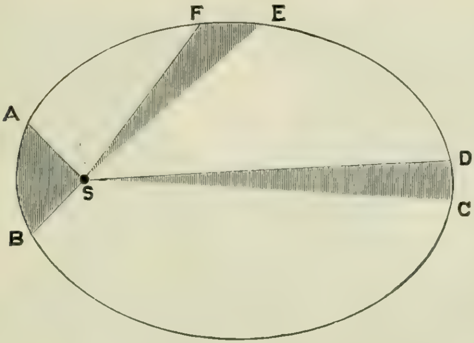


Fig. 166. Illustrating Kepler's second law.

positions of the earth in its course are always sensibly parallel, and now points very nearly to the north polar star.

THE SEASONS: LENGTH OF DAY AND NIGHT.

If the earth's axis were perpendicular to the plane of its orbit, the sun would always shine vertically over some part of the equator, and day and night would be equal over the whole globe. Every place would have 12 hours day and 12 hours night the whole year round, and the heat received from the sun in any particular place would be practically constant; but in consequence of the inclination of the earth's axis, the sun's energy is unequally distributed, and varies at different times of the year, giving rise to the phenomena of the *seasons*. In Fig. 167 the earth is shown

in four positions in its path around the sun. In whatever position the earth is, one-half of its surface is always lighted up by the sun.

AUTUMNAL EQUINOX. When the earth is in position 1, the sun's rays fall vertically over the equator; the *circle of illumination*, dividing the light from the darkness, extends from pole to pole. In one rotation every parallel of latitude will be half time in the light and half time in the darkness, so that day and night will be equal all over the world. This period is called the *autumnal equinox.* It occurs on Sept. 23rd. The sun then

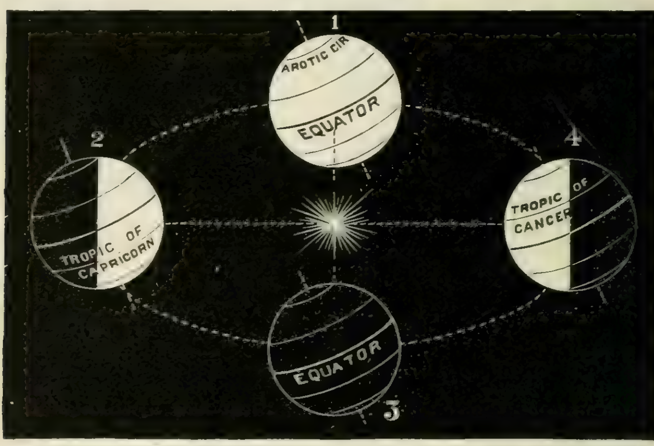


Fig. 167. Illustrating the seasons and the different lengths of day and night.

appears projected on the celestial sphere in the sign Libra. (Fig. 159). This season is *autumn* in the northern hemisphere and *spring* in the southern.

WINTER SOLSTICE. In three months from this time the earth is in position 2. Here the northern hemisphere is turned away from the sun, whose rays now shine vertically over a parallel of latitude 23½ degrees south of the equator, which is called the *tropic of capricorn*, after the sign of the Zodiac in which the sun appears at that date (Fig. 159). This is the farthest point south at which the sun ever appears in the Zenith, and the line indicating

this is called a *tropic*, because here the sun seems to turn north again. The circle of illumination now falls 23½ degrees short of the north pole, the limit being marked by the *arctic circle*, and it extends 23½ degrees beyond the south pole, the boundary here being called the *antarctic circle*. The sun is visible everywhere within the antarctic circle, but all within the arctic circle is then in darkness.

Between the equator and the antarctic circle, it is evident that all places will be in the sunlight for more than half a rotation, so that the days will be longer than the nights. Between the equator and the arctic circle, the reverse will be the case, and the nights will be longer than the days. This is the *winter solstice*, Dec. 21, where the sun seems to stand still before turning north again. The season is *midwinter* in the northern hemisphere and *midsummer* in the southern.

VERNAL EQUINOX. In three months more, the earth having completed one-half its journey, occupies the position represented at 3. This is the *vernal*, or *spring equinox*, the 21st of March, when the sun appears in the sign of Aries (Fig. 159). The circle of illumination again reaches from pole to pole, and day and night are again equal all over the world. It is now spring in the northern hemisphere and autumn in the southern.

SUMMER SOLSTICE. Position 4 represents the earth three months later, just before starting on the last quarter of its journey. Here the conditions of position 2 are exactly reversed, the northern hemisphere is now turned towards the sun, whose rays strike vertically on the parallel of latitude 23½ degrees north of the equator, and as at this time the sun appears in the sign of the Zodiac known as Cancer (Fig. 159), this parallel is called the *tropic of cancer*. The circle of illumination extends beyond the north pole to the arctic circle, and just reaches the antarctic circle, 23½ degrees from the south pole.

In a rotation of the earth while in this position all places within the arctic circle keep in sight of the sun, while to all places within the antarctic circle the sun is invisible. Between the arctic circle and the equator, more than half of each parallel will receive the sunlight, and the

days will be longer than the nights. Between the antarctic circle and the equator the reverse will be true, and the nights will be longer than the days. This is the *summer solstice*, the 21st of June, when it is midsummer in the northern hemisphere, and midwinter in the southern.

It will be noticed that, from the vernal to the autumnal equinox, the North pole is in continual sunlight; hence, it has six months continuous day, and at the same time the South pole has six months continuous night. From the autumnal to the vernal equinox the reverse is the case; the North pole is in darkness for six months and the South pole has six months continuous day. Every place within the tropics has the sun in its zenith twice a year. Between the tropics and the Arctic and Antarctic circles the sun is never directly overhead.

ZONES OF CLIMATE. The heat derived from the sun's rays when they strike the earth vertically is very much greater than when they fall obliquely; consequently, the amount of heat received at any place on the earth's surface will vary with the altitude of the sun at that place.

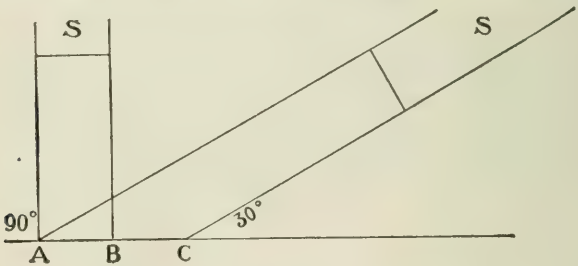


Fig. 168. Sun's rays falling at different angles.

In Fig. 168, a sunbeam is represented, falling first vertically, and second at an angle of 30°. In the latter case the surface covered is twice that covered in the former case, that is A C is just twice A B. The oblique rays have also to traverse a greater thickness of the earth's atmosphere, and so lose more heat by absorption than the vertical rays do.

The length of the day is another factor in estimating the amount of heat received at any place. When the days

are long more heat is absorbed by the earth than is given off by radiation in the short nights, and there will be a gain in the general temperature, but when the days are short and the nights long, the radiation at night will exceed the absorption during the day, and there will be a loss in general temperature. This seasonal variation in temperature will be greatest without the tropics, for it is here that the variation in length of days and nights is greatest.

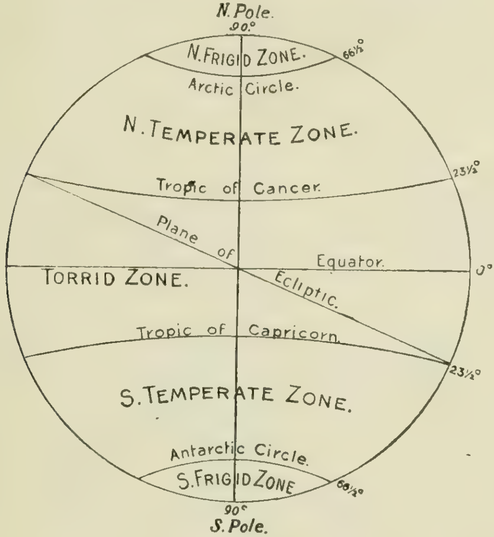


Fig. 169. Zones and Tropics.

In consequence of the unequal distribution of heat from these causes, geographers have found it convenient to divide the earth's surface into five great natural divisions, called *Zones*, or belts, bounded by the tropics and the polar circles. Since the sun is always vertical some place within the tropics, and day and night are about equal, the heat will be great all the year round. This division of the earth is therefore called the *Torrid Zone*. The areas included within the arctic and antarctic circles receive little heat from the sun's rays, and are termed respectively, the *North* and the

South Frigid Zone; while those divisions situated between the polar circles and the tropics and which receive a moderate amount of heat from the sun, are known as the *North* and the *South Temperate Zone*, respectively.

THE MEASUREMENT OF TIME.

In measuring time, as in measuring distance, there must be a unit of measurement. The fundamental unit for the measurement of time is the *day;* for shorter divisions than a day we have *hours*, *minutes*, and *seconds;* for longer divisions the *week*, *month*, and *year*, which are multiples of the day, are used. But there are several different kinds of day, all of them depending on the rotation of the earth on its axis.

Sidereal Day. The interval which elapses between the instant a *fixed star* appears on any meridian, and the instant it returns to the same meridian, is called a *sidereal* day. It is the exact time required by the earth to make a complete rotation. But a star is not a prominent object, nor has it anything to do with producing day and night, so that the time of its apparent motion would not make a suitable unit for regulating the affairs of everyday life.

Solar Day. The interval which elapses from the instant the *sun* appears on any meridian, until it returns to the same meridian, or, from noon until noon, is called a *solar* day. Since the sun is but our nearest star, it might seem that a sidereal day and a solar day should be of the same length. If the earth's only motion were that of rotation, this would be the case, but since the earth, besides turning on its axis, also travels around the sun, it will take a little longer time for any particular meridian to come opposite to the sun again, than would be required if the earth were stationary; hence, the solar day is about four minutes longer than the sidereal day.

In Fig. 170, S represents the sun, the two parallel lines are rays from the same distant fixed star. When the earth is in position 1, both the sun and the star are opposite the meredian A.M.; when in position 2, after one complete revolution of the earth, the *fixed star* is again on the

meridian at A, but the earth must turn a little farther through AB, before the *sun* is again on the meridian at A.

The time required for the earth to turn through this distance is the excess of a solar over a sidereal day. Sidereal days are all of the same length, but since the earth moves faster in some parts of its orbit than in others, the advances made along its path at each rotation on its axis are not the same; hence, the length of the *apparent* or *true solar day*, as it is called, is not uniform. It is longest when the earth moves fastest, and shortest when the earth moves slowest. Thus, neither the sidereal day, nor the apparent solar day, would make a suitable standard for the measurement of time.

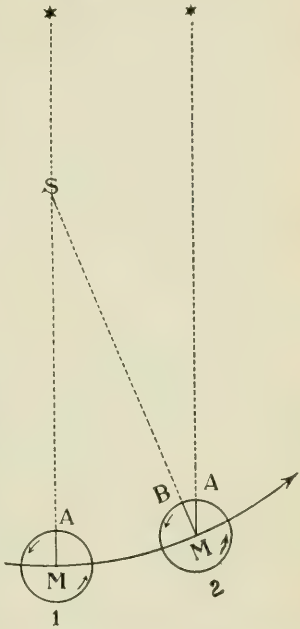


Fig. 170. Illustrating difference in length between sidereal and solar day.

Mean Solar Day. To obtain a satisfactory measure of time, the average of all the apparent solar days is taken, and this is called a *mean solar day*. This is always of the same length, and is divided into 24 hours. Our clocks and watches keep mean solar time. Therefore, when the sun crosses the meridian, the clock will not always indicate noon, but will usually be a little too fast, or a little too slow. The difference is called *the equation of time*, that is, the difference between true sun time (apparent solar time) and mean sun time (clock time). The equation of time for every day in the year may be calculated and is given in the Nautical Almanac.

To find mean solar noon (12 o'clock) at any place, true (apparent) noon is first found by observing through a transit telescope the exact moment when the sun is

opposite the meridian of the place, and this time, plus or minus the equation of time, gives local noon.

The mean solar day, which is the day of civil life, begins and ends at midnight. The astronomical mean solar day begins at mean noon, and the hours number from 1 to 24. Thus, instead of "1 a. m.," the astronomer would say, "13 hours."

This method of counting the hours from 1 to 24 has been adopted in parts of Canada, especially in the North-West, but the day begins and ends at midnight, not midday. Pupils assemble in school at 9 o'clock, are dismissed for noon at 12 o'clock, reassemble at 13 o'clock and are dismissed for the day at 16 o'clock. The faces of clocks and watches are marked so that the hours number from 1 to 24. This method of reckoning time gets rid of the abbreviations a.m. and p.m., which is a decided advantage, especially in preparing and using railway and other time-tables.

There are $366\frac{1}{4}$ sidereal days in a year, but only $365\frac{1}{4}$ solar days, so that the earth rotates once oftener than there are days in the year.

Kinds of Years—Sidereal Year. Just as the rotation of the earth on its axis determines the length of the day, so its revolution around the sun determines the length of the year.

When the sun is exactly between the earth and a fixed star, the two latter are said to be in conjunction, and the time which elapses between two consecutive conjunctions with a given fixed star is called a *sidereal year*. Its length is 365 days, 6 hrs., 9 min. and 9 sec. It is the exact time required for the earth to revolve around the sun.

The Tropical or Equinoctial Year. This is the time taken by the sun to pass from one vernal equinox, to the next succeeding one. If the vernal equinoxes always occurred at the same time, a tropical year would be of the same length as a sidereal year, but owing to a slow shifting of the equatorial plane, by which the vernal equinox advances each year along the ecliptic, to meet the sun—a phenomenon known as the *precession of the equinoxes*—the tropical year is shorter than the sidereal year, by about 20 minutes. Its length is about $365\frac{1}{4}$ days.

The Civil Year. As a fraction of a day in a year would be inconvenient, the ordinary, or civil year, is made to contain 365 days; but the Tropical year contains $365\frac{1}{4}$ days nearly, a difference which is made up by regarding every

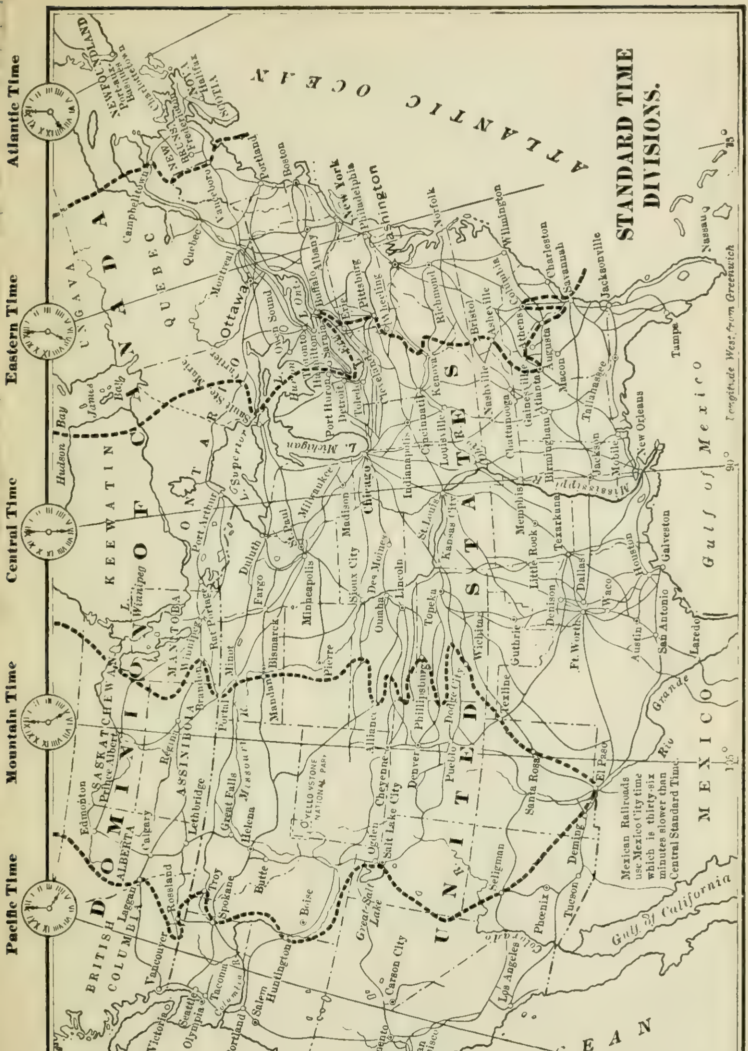

STANDARD TIME DIVISIONS.
Pacific Time
Mountain Time
Central Time
Eastern Time
Atlantic Time
Mexican Railroads use Mexico City time which is thirty-six minutes slower than Central Standard Time.
Longitude West from Greenwich
ATLANTIC OCEAN
PACIFIC OCEAN
Gulf of Mexico
DOMINION OF CANADA
UNITED STATES
MEXICO

Figure 171.

fourth year as a "leap" year, containing 366 days. But the difference not being quite a quarter of a day, it is more than made up, the excess amounting to about 3 days in 400 years. This excess is provided for by arranging that centuries not divisible by 400 instead of being regarded as leap years shall have only 365 days. Thus the year 1900 was not a leap year, but the year 2000 will be a leap year. By this arrangement the lengths of the tropical year and the civil year are made to coincide almost exactly.

STANDARD TIME. In order to facilitate railroad traffic, some countries have to some extent adopted what is known as *standard* time. Each region is marked off into belts 15 degrees in width, running north and south, and all parts of each belt have a uniform time, which is that of the meridian running through the centre of that belt. This time is an even number of hours slower, or faster, than Greenwich mean solar time. The time in any part of one belt differs from that in any part of an adjacent belt by just one hour.

In Canada and the United States there are five such divisions, and therefore five standard times.

Atlantic	or 60th	meridian	time is	4	hours	slower	than	Greenwich.
Eastern	" 75th	"	"	5	"	"	"	"
Central	" 90th	"	"	6	"	"	"	"
Mountain	" 105th	"	"	7	"	"	"	"
Pacific	" 120th	"	"	8	"	"	"	"

By a glance at the map on page 395 it will be seen that the boundaries of the different time-belts do not run parallel to the central meridians, but take a zigzag course to suit the location of certain cities and towns, and to accommodate the railroad world.

DETERMINATION OF LATITUDE AND LONGITUDE.

In order to define accurately the position of any place on the earth's surface we must know its latitude and longitude.

LATITUDE. The latitude of a place may be defined as its angular distance from the equator. This will correspond to its zenith distance from the celestial equator. It is always equal to the altitude of the pole above the horizon, as is shown in Fig. 172.

Suppose R to be the place of an observer on the earth. E E_1 the equator. P O, the axis indefinitely prolonged to P_1. H H_1 the horizon of R and Z its zenith. The number of degrees in the angle R O E_1 will be the distance of R from the equator, and therefore its latitude. The observer at R sees the celestial pole along the line of R P_2 which is sensibly parallel to O P_1 owing to the great distance of the pole of the heavens. The angle H R P_2 will then represent the elevation of the pole above the horizon H H_1, but from the construction of the figure this is evidently equal to the angle R O E_1, *i.e.*, the latitude of R is equal to the elevation of the pole above the horizon.

This may be experimentally verified. To an observer on the equator the north pole of the heavens would appear on the northern horizon, and the south pole on the southern horizon. If he were to travel north, the south pole would disappear from view, while the north polar star, which is very near the north pole of the heavens, would rise higher and higher as he advanced, until, by the time he reached parallel 45°, or half way between the equator and the pole, the polar star would be 45° above the northern horizon, and if it were possible for him to reach the north pole of the earth, or 90° latitude, the polar star would be in his zenith, or 90° above his horizon. Hence the latitude of a place is always determined by finding in one way or another the altitude of the celestial pole above the horizon of the observer.

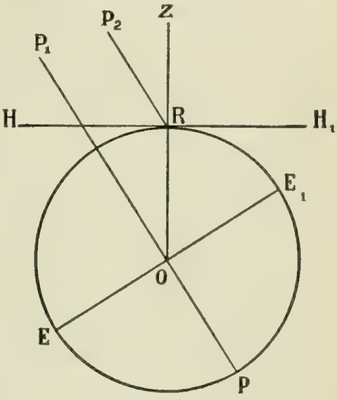


Fig. 172. Illustrating latitude.

One way of finding the altitude of the pole is by taking the altitude of any circumpolar star, first, when it is at the highest point of its rotation, and again, when at its lowest point; the mean of these two will give the latitude of the observer.

Another method is to take the meridian altitude of a star whose declination is known. From the declination we get the polar distance; add this to the altitude, and subtract the sum from 180°, and the result is the latitude. At sea the latitude is usually found by taking the altitude of the sun with a sextant when on the meridian, adding to this the sun's

declination for that day, if the sun is south of the equator, or subtracting it, if the sun is north of the equator; this result subtracted from 90° will give the latitude.

LONGITUDE. As has already been stated, this is the angular distance of a place east or west of a first meridian. As the earth turns from west to east through 360° in 24 hours, it will turn through 15° in one hour. Thus, a difference of 15° of longitude between two places on the earth's surface will make a difference of one hour in time. Longitude is reckoned 180° east or west of some particular meridian, called the first meridian, which for most nations is that which passes through the observatory in Greenwich, England. To find the longitude of any place, all we need to know is the difference in time between Greenwich noon and local noon, mean solar time. If local time is faster than Greenwich time, the longitude of the place is east; if slower, the longitude is west.

If we connect by electric telegraph a place whose longitude we wish to know with one whose longitude we know, and ascertain accurately the difference in time, at any instant, between the two places, the longitude of the first place may be found.

At sea, local time is found by observing the sun's meridian passage, which will give apparent noon; then by using the equation of time, mean noon is obtained. In this way the captain's watch is regulated to show local time. If now Greenwich time can be obtained, the longitude can be easily calculated. Greenwich time is ascertained from a chronometer, "the ship chronometer," which is carried for that purpose, and which is carefully guarded from any chance of injury. From the difference between these two times the longitude is obtained. For example if the captain's watch, regulated as described, shows local time to be 9 o'clock a. m. when the ship's chronometer shows Greenwich time to be 2.20 p.m., the longitude is 80° west.

ADDING AND DROPPING A DAY. A traveller proceeding eastward from any given meridian meets the sun before the earth has completed a rotation; the sun rises later each day and sets earlier each night. For every fifteen degrees of longitude travelled over, he is obliged to move the hands of his watch forward one hour in order that it may coincide with local time, and by the time he completes his journey around the earth, and arrives at the meridian from which he started, he will have passed over 360° and will have gained 24 hours, or a day. He will have made one turn more with respect to the sun than if he had remained at home. On the other hand, a traveller going around the world in a westerly direction finds local time continually getting slower, and for every 15 degrees travelled over he puts his watch back one hour, or 24 hours in making the entire journey. He will have made one turn less than if he had remained at home, and will have lost a day. In order to avoid confusion in dates, a day is

dropped by mariners going eastward when they cross the meridian of 180° from Greenwich, and a day is added when they cross the same meridian going westward.

THE MOON.

Whether the earth and the moon entered upon their respective careers as separate masses of matter, or whether they originally formed one planet, and subsequently parted company, the moon being thrown off by the too rapid rotation of the aggregate mass when in a more or less fluid condition, certain it is that the physical characteristics of the moon justify the belief that both earth and moon are offspring of the same parent.

The moon accompanies the earth in its journey around the sun, both bodies whirling about their common centre of gravity, which is situated about 1,200 miles within the earth's mass.

Like the earth and the other planets, the moon is an opaque spherical body, shining by reflected light. Though 240,000 miles away, it is by far the nearest celestial object to the earth. It is on this account that it appears almost as large as the sun, while, comparatively, it is an insignificant body, only 2,160 miles in diameter. The area of its surface is only about $\frac{1}{14}$ of the area of the earth's surface; and it would take 49 moons to make one earth in size. It is nearly $3\frac{1}{2}$ times heavier than a moon composed of water would be, while the earth is $5\frac{1}{2}$ times heavier than if composed of water. The force of gravity on its surface is only one sixth of that on the earth's surface, so that a boy on the moon could throw a stone 6 times higher than he could on the earth.

REVOLUTION OF THE MOON. That the moon makes a monthly circuit in the heavens is a fact with which everyone is familiar. At certain times, just after the sun sinks below the horizon, we see our satellite low in the western sky as the new moon. On each succeeding evening we see it farther and farther to the east, until in two weeks time it rises in the east as the full moon, about the time the sun is sinking in the west. During the next two weeks it continues its easterly course, until at the end of about $29\frac{1}{2}$ days it again emerges from the sun's rays as the new moon, and thus completes its circuit. Its orbit, like that of the

other planets, is in the form of an ellipse. When the moon is in that part of its orbit nearest the earth, it is said to be in *perigee*, and when in that part most remote from the earth it is said to be in *apogee*.

Relatively to any fixed star, the moon completes its revolution about the earth in $27\frac{1}{3}$ days, but it requires about $29\frac{1}{2}$ days for it to occupy the same relative position to the sun as at the beginning of its monthly course, or, to go from new moon to new moon. The reason for this is, that the sun has had an apparent motion towards the east among the fixed stars during the whole month, due really to the earth's motion in its orbit, and the moon will have to move forward some 30 degrees to overtake the sun. This will be made clear by a diagram. In Fig. 173 S represents the sun, the large circle the earth's orbit, and the small circle, the orbit of the moon around the earth. Suppose when the earth is at E the moon is at M. Then if the earth moves to E_1 in $27\frac{1}{3}$ days, the moon will have completed a revolution relative to the star, that is it will be at M_2, the lines $E_1 M_2$ and E M from a fixed star being sensibly parallel, but new moon will not occur yet, because the sun is not in the same direction as before, and the moon must move through the additional arc $M_2 M_1$, and a little more, before it will again be new moon.

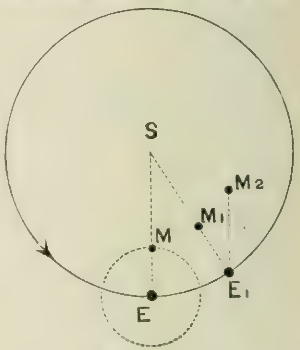


Fig. 173.

KINDS OF MONTHS. The time occupied by the moon in passing from one star to the same star again, is called the *sidereal month*. This is equal to 27·32 days. The interval from new moon to new moon, or the time occupied by the moon in passing from the sun around to the sun again, is called the *synodic month*. This is slightly variable, on account of the varying speed of the earth in its orbit. Its mean length is 29·53 days. This is called a *lunar month*. The *calendar month* is the month recognized in civil life, and is made up of different numbers of whole days, as 30, 28 and 31.

PHASES OF THE MOON. In its revolution about the earth, the moon assumes many different appearances, at one time taking the form of a crescent, at another that of a half moon, at another that of a full moon, and so on. These are called the moon's *phases*. They result

from the moon, as it revolves around the earth, acting as a great spherical reflector of the light falling on it from the sun. It is clear that the sun can light up only that half of the moon which is turned towards it, and that the appearance of the moon will vary according to the area of its illuminated hemisphere visible from the earth.

In Fig. 174 the sun is supposed to shine from the right. The inside circle of half-lighted spheres represents the moon in eight different positions as seen from the sun. The

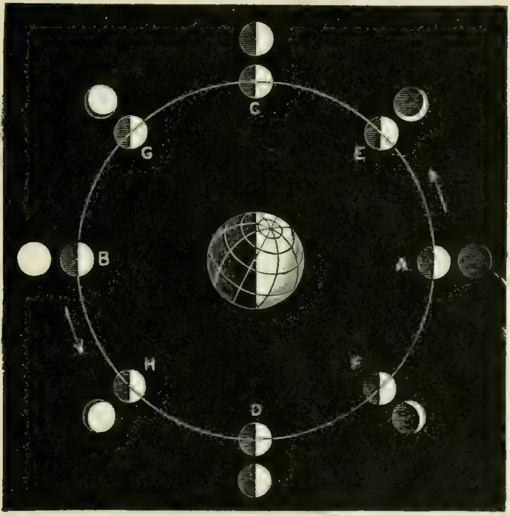


Fig. 174. Phases of the moon. The sun shines from the right.

outside circle of figures represents the moon in the same positions as seen from the earth.

At A the moon is nearly between the earth and the sun, and we have "new moon." Its dark hemisphere is turned towards the earth so that the moon is invisible. As the moon moves on a little in its course around the earth, an observer on the earth sees a small portion of the illuminated hemisphere in the form of a crescent as at E. At C the moon is in its "first quarter" and one half of the illuminated hemisphere is visible. At G three-fourths of its illumin-

ated hemisphere is visible, and at B an observer on the earth can see the whole hemisphere of the moon lighted up. In this position the moon is opposite the sun and it is "full moon."

Continuing its course the same appearances are repeated in reversed order, and the moon is said to *wane*. It is "gibbous" at H; in its "last quarter" at D; crescent-shaped at F; and new moon again at A, when the cycle recommences. The horns of the crescent moon are always turned away from the sun, so that in its earlier phases they point towards the left, and in its later ones towards the right.

Immediately before and after new moon, in addition to the crescent-shaped part which is brightly illuminated, we sometimes see the remainder of the moon's disc dimly lighted up. This phenomenon, "the old moon in the new moon's arms," is caused by that portion of the moon reflecting to us the light it receives from the earth. The bright part also seems to belong to a larger sphere than the dark part. This is due to what is called *irradiation*, an optical effect by which the size of a bright body on a dark background becomes somewhat exaggerated.

ROTATION OF THE MOON.

The most casual observer must notice that when any considerable portion of the moon is visible the markings on its surface always appear the same; "the man in the moon" always presents himself to the view, wearing the same expression. The reason is that the same side of the moon is always turned towards the earth. This arises from the fact, that the moon rotates on its axis in the same time and in the same direction that it revolves around the earth. One can easily illustrate this by walking around an object in a room, always facing the object. In doing so, his body must have made a complete revolution, as he has faced all sides of the room in succession. There are indeed certain small irregularities of motion termed "librations," in consequence of which we obtain a glimpse of a narrow strip of the farther hemisphere, now at one edge, and again at another, but the greater portion of this hemisphere must forever remain invisible to dwellers on the earth.

ECLIPSES. Since light travels in straight lines, a great spherical light-giving body like the sun will send its rays in all directions. The planets, being opaque bodies, will each intercept its share of this light, and thus cast into space a long conical shadow always pointing directly away from the sun. A body entering into one of these shadows is said to suffer an *eclipse*.

The eclipses of greatest interest to us are those of the sun and the moon. An eclipse of the sun is caused by the moon coming between the earth and the sun, and an eclipse of the moon results when the earth comes between the moon and the sun. In the first case a shadow of the moon will be cast on the earth, and in the second case a shadow of the earth will be thrown on the disc of the moon.

If the plane of the moon's orbit coincided with the plane of the ecliptic, then at every new moon we should have an eclipse of the sun, and at every full moon an eclipse of the moon. But since the moon's path is inclined to the ecliptic about 5°, one half of its journey is performed above that plane, and one half below it, and, therefore, twice in each revolution, the moon is at those points where its orbit intersects the plane of the ecliptic. These points are called *nodes*. If the moon at such times happens to be new or full, that is, in a line with the earth and sun, we shall in the first case have an eclipse of the sun, and in the second an eclipse of the moon. During the rest of its journey the moon is either too far above or too far below the earth's orbit for one body to enter the shadow of the other.

In the diagram, Fig. 175, S represents the sun, E the earth, M and M_1, the moon in two positions—new moon at M, and full moon at M_1. The level of the paper represents the plane of the ecliptic. At M the moon intercepts the light of the sun, and its shadow, falling on the earth, produces an eclipse of the sun. At M_1, the earth intercepts the sun's light, and the moon, passing into the shadow cast by the earth, suffers an eclipse.

In the diagram, the dark cone-shaped shadow U where no light falls, is called the *umbra*, while the fainter shadow, P where partial light is received, is called the *penumbra*,

ECLIPSES OF THE MOON. When an eclipse of the moon occurs the advancing edge first enters the penumbra, but without any very marked loss of light. As the moon enters the umbra, however, that portion of the disc within it is entirely lost to view and the circular shape of the earth's shadow is seen marked out by an ill-defined line as represented in Fig. 176.

In a total eclipse the whole of the moon gradually passes into the umbra, but is seldom completely obscured, the entire disc being usually dimly visible, tinged with a reddish copper-colored light. This is due to the sun's rays being refracted by the earth's atmosphere towards the moon, which then reflects them back to the earth, at the same time most of the blue and green rays are absorbed, which accounts for the red color, just as the sun seems red when setting. A total eclipse of the moon can not last longer than about two hours.

If the moon is not near or at a node, it will not pass completely into the umbra of the earth's shadow, and we shall get only a *partial eclipse*, as seen in Fig. 176, the extent of the eclipse depending on the distance from the node. If the moon is to the north of the node the lower edge may be obscured; if to the south, the upper edge may enter the earth's shadow. If the moon is more than 12° from the node there can be no eclipse. By reference to Fig. 175 it

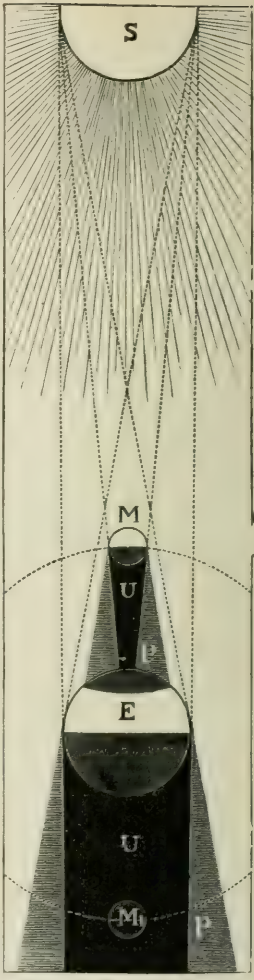


Fig. 175. Eclipses of the sun and the moon.

will be seen that a lunar eclipse will be visible at any part of the earth in which the moon itself is visible.

ECLIPSES OF THE SUN. By again referring to Fig. 175, the shadow cast by the moon is seen to take the form of a cone, which is just about long enough to reach the earth. The length of this cone varies with the moon's distance from the sun. Its greatest length is 236,000 miles, while the moon's mean distance from the earth is 238,000 miles. Owing, however, to the elliptical form of the moon's orbit, a considerable part of its course is described at a good deal less than the mean distance, so that about the time of perigee its *shadow-cone* may reach the earth and cause a total eclipse of the sun. The area of the earth's surface in complete darkness is never very large, as the diameter of the moon's shadow-cone cannot exceed 167 miles. By reference to Fig. 175 it will be seen, however, that the space covered by the penumbra, within which the eclipse is partial, is considerably larger.

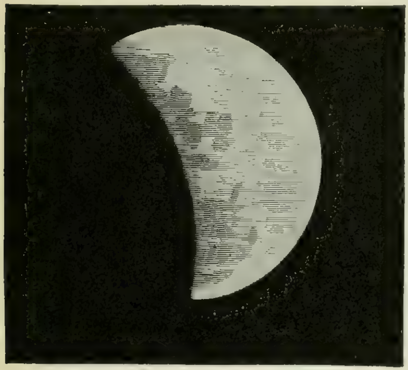


Fig. 176. Moon partially eclipsed.

The time during which an eclipse of the sun can be total at any place, depends on the diameter of the shadow-cone, which in turn depends on the distance of the moon from the earth when the eclipse occurs. The period of totality in any one locality varies from a few seconds to about seven minutes. The shadow sweeps over the earth in a narrow track, with great rapidity, and of course the eclipse is visible only at those places swept by the shadow.

When the moon is farthest from the earth, or in apogee, at the time of the solar eclipse, its shadow is not long enough to reach the earth, and the dark body of the moon, which then looks smaller than the sun, will be seen pro-

jected on the disc of the latter, surrounded by a luminous ring. This is called an *annular eclipse* of the sun (Fig. 177). It is obvious that an annular eclipse of the moon is impossible.

"A total eclipse of the sun is at once one of the most awe-inspiring and grandest sights it is possible for man to witness. As the eclipse advances, but before the totality is complete, the sky grows of a dusky livid or purple, or yellowish crimson color, which gradually gets darker and darker, and the color appears to run over large portions of the sky, irrespective of the clouds. The sea turns lurid red. This singular coloring and darkening of the landscape is quite unlike the approach of night, and gives rise to strange feelings of sadness. The moon's shadow is seen to sweep across the surface of the earth, and is even seen in the air; the rapidity of its motion and its intenseness produce a feeling that something material is sweeping over the earth at a speed perfectly frightful. All sense of distance is lost, the faces of men assume a livid hue, fowls hasten to roost, flowers close, cocks crow, and the whole animal world seems frightened out of its usual propriety."

Fig. 177. Annular eclipse of the sun.

PHYSICAL FEATURES OF THE MOON. Through a moderately good telescope the moon can be viewed as if it were situated only a few hundred miles away. By this means, and also by taking advantage of modern photography, astronomers have carefully studied the surface of the moon which is turned towards the earth, and have mapped it out with considerable minuteness. To the unaided eye the moon's surface presents dark and light patches of various shapes. The telescope reveals the dark portions as great plains, or dried-up *sea bottoms*, while the lighter portions are the *lunar mountains*, which reflect the sun's light and thus appear brighter by contrast than the plains, which are somewhat in the shadow.

The best time to view the moon's surface is just before or after the time of half moon, when the sun shines obliquely on it. The shadows of the high peaks then stand

Fig. 178. Surface of the moon from a photograph.

out prominently, and the *terminator*, or boundary line between the illuminated and shaded portions, presents an irregular jagged appearance.

But the most remarkable physical feature of the moon's surface is its extinct *volcanic craters*. The great number of these and the immense size of some of them indicate past volcanic action in the moon, and on a scale far surpassing anything known on the earth at the present time. Many of these craters have been carefully studied and their measurements taken. One of the most conspicuous, named Newton, has walls over 20,000 feet high. Another, named Copernicus, is about 60 miles in diameter, and has walls rising in places to a height of 11,000 feet above the bottom of the crater. The larger craters are usually surrounded by smaller ones, as seen in Fig. 179. Besides volcanic moun-

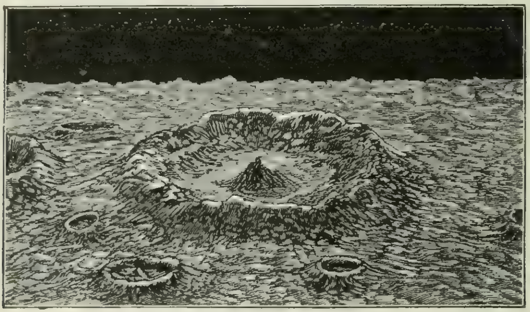


Fig. 179. Lunar Crater.

tains with their craters, there are ordinary mountain ranges and isolated peaks, some of which are but slightly inferior in elevation to those on our earth. Radiating away from the volcanic craters are certain markings technically known as "rays" and "rills," the former probably comparable to dykes of basaltic trap on the earth, the latter to great fissures or canyons.

As there is no evidence of refraction when the moon passes between the earth and a star, the star disappearing instantly, and as there is an entire absence of clouds of any kind, it is believed that the moon has no atmosphere. If

there is no atmosphere there can be no water on its surface, as the water would evaporate and produce an atmosphere of water vapor.

As the moon rotates on its axis very slowly, the difference in temperature between the side next the sun, and that turned away from the sun, must be very great, and as there is no atmosphere to retard radiation, the temperature on the side turned away from the sun must fall below even the lowest that has ever been obtained artificially on the earth. From all the evidence, the moon seems to represent the most advanced stage in planet life yet attained, and to be a cold, barren mass of rock—a dead world.

It is a popular belief that the moon exercises an influence over the affairs of earth ; that if the horns of the crescent moon point in a particular direction it is a "wet moon"; if in another direction a "dry moon"; that hogs should be killed, seed sown, and grain cut at certain times of the moon. It is almost needless to say that these beliefs are unsupported by any scientific evidence whatever, and must be ranked as superstitions. The only appreciable influences the moon has on the earth, arise from the light which it reflects from the sun, and from the attraction which it exerts on our planet, one effect of which is seen in the ocean tides.

THE SUN.

To dwellers on the earth, the sun is by far the most conspicuous object in the universe. It is the source of all those forms of energy which make life on earth a possibility; yet it is but one of the innumerable stars that dot the heavens, and if removed to the average distance of a star of the third magnitude, it would be so reduced in brightness, as to be barely visible to the naked eye. It is only on account of its comparative nearness to us, that it surpasses all the other stars in glory. The sun is 93,000,000 of miles distant, while the nearest fixed star is 25,000,000,000,000 miles from the earth. If at the birth of Christ, a carrier pigeon, flying 100 miles a day every day in the year, had started with a message from the earth to the sun, it would not be able to deliver the message until the year 2,545. It might have rested on the planet Venus about the time of Alfred the Great, and on Mercury shortly after Queen Elizabeth ascended the throne of England.

The diameter of the sun is about 110 times the diameter of the earth, but the matter composing its mass has only about one-quarter of the density of that composing the earth's mass. Its force of gravity is such that a body on its surface would weigh 28 times as much as on the earth's surface, and would fall 28 times as far in one second of

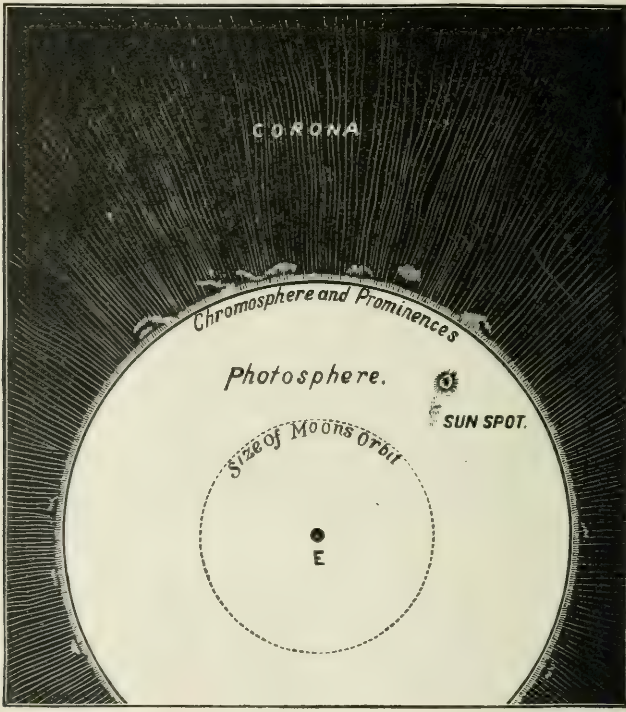


Fig. 180. The Sun.

time. The spectroscope shows that the chemical nature of the sun is similar to that of the earth. About one-half of the elements found in the earth have been shown to be present in the sun. These are mostly metals, and on account of the high temperature of the sun they exist as gases at or near its surface and not as solids as we know

most of them to be here. The high temperature of the sun, probably between 5,000 and 10,000 degrees Centigrade, accounts for the low density of its materials, notwithstanding the enormous pressure exerted upon it by gravity, and which must tend to compress it and render it more dense.

THE SUN'S PHOTOSPHERE. The white radiant surface of the sun, as seen by the unaided eye, is called the photosphere (light sphere). Through a good telescope, it shows a granulated or fleece-like appearance,

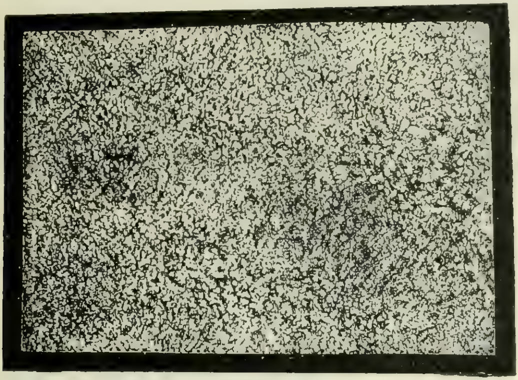


Fig. 181. Appearance of Photosphere.

as if composed of small clouds interspersed with darker spaces. (Fig. 181). These small clouds are probably due to ascending currents of highly heated vapors, and the darker patches to cooler descending currents.

CHROMOSPHERE AND PROMINENCES. During a total eclipse of the sun, certain red-colored irregular prominences appear around the outer edge of the photosphere. These are projections from a similarly colored envelope, of no great thickness, known as the *chromosphere*.

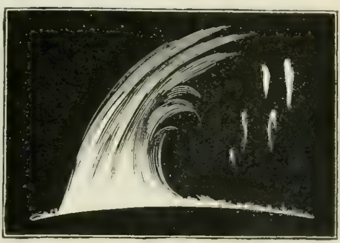


Fig. 182. A typical prominence.

These prominences sometimes rise as high as 200,000 miles above the photosphere, portions of which they may carry with them. They are supposed to be tongues of gas, probably hydrogen, in an incandescent state.

THE CORONA. Outside of the chromosphere is a much more extensive envelope known as the *Corona*. (Fig. 180). This is seen only during a total eclipse, and reveals

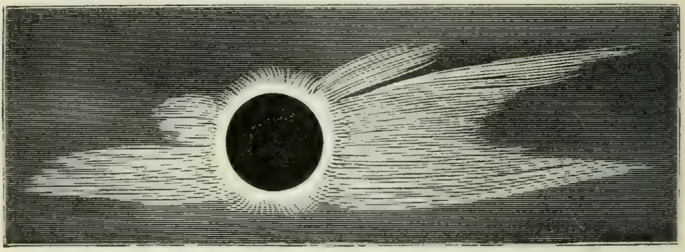


Fig. 183. Eclipse of sun 1889, showing corona.

itself then as a bright, radiant sheen, or halo of soft light, completely surrounding the sun, and filling a space more than twenty times as large as the sun itself. Though of great extent its density is inappreciable, as comets seem to pass through it without any apparent resistance. It is probably composed of infinitesimally small particles, thrown off from the sun with velocity sufficient to carry them millions of miles from the sun's photosphere.

Fig 184. Eclipse of sun 1860, showing corona.

SUN SPOTS. The photosphere of the sun seems to consist of a vast ocean of incandescent matter in a state of violent commotion. Great chasms, or rents in this, are known as *sun spots*. (Fig. 185.)

These are not permanent features of the sun's surface, but may change their size and contour in a few days. One may often see them on the sun's disc by looking through

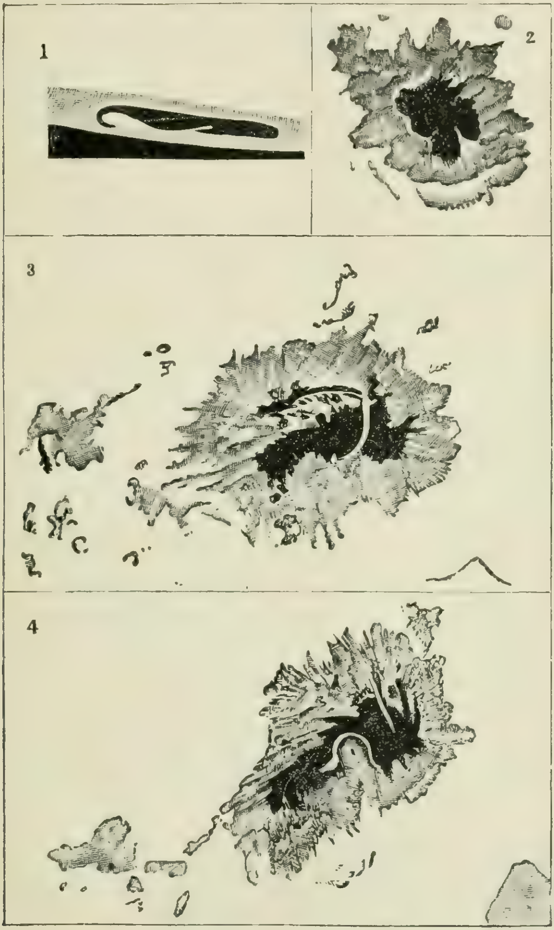


Fig. 185. Changes seen in the great sun spot of 1865, in eight days. In No. 3 a "bridge" has formed.

a piece of smoked glass. A normal sun spot has a dark central area, known as the *umbra* or *nucleus*, surrounded by a less dark, irregular border, called the *penumbra*. Such a spot may entirely change its shape in a short time, and may break up into a group of spots crossed by "bridges," finally filling up and disappearing altogether. Spots are of various sizes; sometimes they reach enormous dimensions, the umbra alone measuring as much as 50,000 miles in diameter, while groups of spots often exceed this size.

SUN'S ROTATION. At times, these spots begin at the left hand edge of the sun, move right across the sun's disc, disappear at the right-hand edge, and after a time, reappear at the left-hand edge of the disc again. When this occurs at the sun's equator the average time of revolution is 25 days; but, curiously enough, they require a little longer to complete a revolution in latitude 40° north or south. This shows that the sun probably rotates on its axis in about 25 days, but not as a rigid body like our earth.

PERIODIC OCCURRENCE OF SUN SPOTS. The history of sun spots shows that they have periods of activity in which they occur in great numbers, followed by intervals of about equal duration, in which they almost entirely disappear. The time between periods of greatest activity averages about 11 years. Thus 1871, 1883 and 1893, were years of sun-spot activity, while 1879, 1889, and 1900 were years in which there were few sun spots. The next period of maximum activity should occur about the year 1905.

Like many other natural phenomena which are but imperfectly understood, a variety of influences has been attributed to sun spots, for which they may or may not be accountable. It seems certain, however, that there is a close connection between magnetic phenomena on the earth and the occurrence of sun spots. The periods of greatest sun-spot activity are the periods in which magnetic disturbances, such as increased daily oscillations of the magnetic needle, magnetic storms, etc., are greatest. Auroras are most active also at such times. The connection between these phenomena has not yet received a satisfactory explanation.

THE SUN'S ENERGY. Of the sun's radiant energy, only one part in every two thousand millions falls on the earth; the other planets also intercept a small fraction. The rest of this energy is radiated into space, and one of the greatest problems in solar physics is to give a satisfactory explanation of how this total enormous output is maintained continuously without any apparent loss. It cannot be the result of combustion. The geological history of the earth shows that the sun has for ages been supplying light and heat to our planet, and no fire could

last so long. Nor can it be that all this energy is derived from the cooling of the sun's mass from an original state of incandescence: such a source of light and heat would have been exhausted long ago. There is no escape from the conclusion, that the sun must have some means of continually renewing its supply of radiant energy.

The theory now generally accepted is that the sun is an incandescent gaseous mass; that it was condensed from a nebulous condition under the influence of gravity; and that this force is still condensing and compressing the sun's material, and thus producing the great supply of heat, which is being continually radiated into space, to be renewed again and again by further compression and contraction. When this contraction can no longer continue, the heat-waste will no longer be replenished, and in time the sun will cease to give out light and heat. This is known as Helmholtz's theory. Lord Kelvin describes it as follows: "At some period of time, long past, the sun's initial heat was generated by the collision of pieces of matter gravitationally attracted together from distant space, to build up his present mass; and shrinkage, due to cooling, gives, through the work done by mutual gravitation of all parts of the shrinking mass, the vast heat-storage capacity, in virtue of which the cooling has been, and continues to be, so slow."

CHARACTERISTICS OF THE PLANETS.

MERCURY. The planet Mercury, on account of its proximity to the sun, is a difficult object to study. It is believed to have little if any atmosphere. Like the moon, it rotates on its axis in the same time that it performs its revolution about the sun; hence, the same side of the planet is always turned towards the sun. On that side there must be perpetual day with a torrid heat, and on the other perpetual arctic night.

VENUS. This planet is about the same size as our earth. It is usually hidden from view by an atmosphere of dense clouds, so that little is known of its real surface. Its cloud-laden atmosphere reflects the sunlight so brilliantly that when near the earth Venus is a very conspicuous object

in the heavens. Its rotation period is believed by many astronomers to be the same as its revolution period. Both Venus and Mercury present phases similar to those of the moon.

MARS. At certain times in its course Mars is comparatively near the earth, and may then be studied more minutely than any of the other planets. Its days and nights are about the same length as ours. Its year is

Fig. 186. Surface of Mars showing the dark (shaded) and bright areas, and the so-called "canals."

about twice as long as ours, and is divided into four seasons, each of which is proportionately longer than the corresponding one on the earth.

The surface of the planet is always plainly visible when near the earth, which would seem to indicate a very clear atmosphere, or one of little density. The atmosphere not being of a nature to prevent active radiation, many astronomers conclude that Mars must have a very low temperature, which they place many degrees below zero.

Other astronomers give the planet a less rigorous climate, and certain white spots near the poles, which disappear during the summer season and appear again during the winter, are considered by them to be snow-caps or snow-fields, the melting of which in the summer season accounts for their disappearance until the succeeding winter season.

Through the telescope the surface of Mars appears diversified by dark-colored and bright-colored areas. (Fig. 186.) These were formerly thought to be seas and continents, but the absence of clouds in the atmosphere seems to preclude the supposition that water exists on the planet in quantities such as seas of this size would indicate. The darker patches are now believed to be low-lying areas with just water enough to produce and maintain a permanent vegetation, and the brighter patches to consist of scorched and barren land.

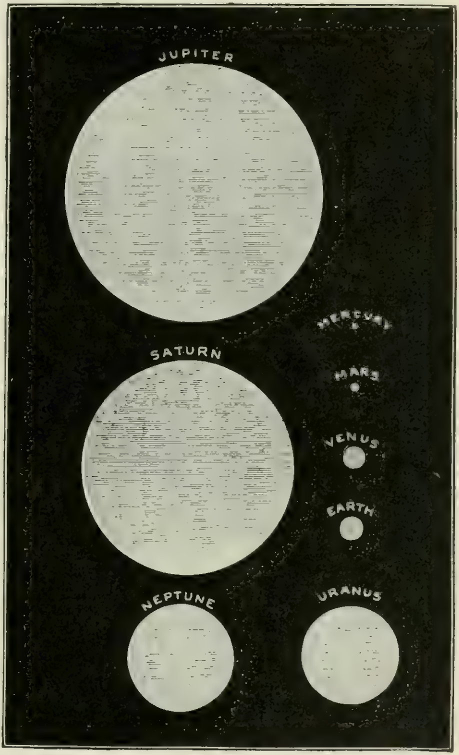


Fig. 187. Relative sizes of the planets.

The brighter portions are intersected in all directions by faint dusky lines, which communicate with the darker parts. These are the so-called "canals" of Mars. There has been a great deal of speculation as to the real nature of these linear markings. Astronomers who have given much time to their study regard them as watercourses with strips of vegetation on either side.

That they are part of an extensive scheme of artificial irrigation, as has been suggested by some, and hence are an indication that the planet Mars is inhabited, and that, too, by a race of beings more advanced

in civilization than the people on the earth, is of course pure supposition.

JUPITER. This planet is larger than all the others combined. On account of its rapid rotation on its axis it is much flattened at the poles, the difference between its polar and equatorial diameters being over 5,000 miles. As its axis is almost perpendicular to the plane of its orbit there can be no seasons. Little of the real surface of Jupiter is ever visible through the telescope, on account of its dense and cloudy atmosphere. The so-called belts, or zones, of Jupiter, the general course of which is parallel to the equator, form a striking feature of the planet and are probably due to great rifts in the clouds. Another prominent feature is the presence of extensive oval spots on the surface. The most remarkable of these is the great *red spot* in the southern hemisphere, 28,000 miles in length, first seen in 1877. (Fig. 188.)

Fig. 188. Jupiter, showing belts, and the great red spot in the southern hemisphere.

There are reasons for believing that, while probably not hot enough to emit much light, Jupiter has nevertheless a very high temperature, and that the planet is composed, in great part, of gaseous matter, the cooling process not having reached the stage represented by the earth.

SATURN. This planet is next to Jupiter in size, and, omitting Jupiter, is larger than all the remaining planets together. Like Jupiter, Saturn is also very much compressed at the poles, and for a similar reason. The difference between the two diameters of the planet is 7,000 miles. Its surface also shows a belted appearance, similar to that of Jupiter, but not so well defined.

The most remarkable physical feature of Saturn is its system of rings, encircling the planet parallel to its equator, and reflecting sunlight like the planet itself.

These are two in number, or they may be considered as one with a clearly marked space of over 2,000 miles dividing it into two parts. The inner edge of the inner ring, which is 10,000 miles from the globe of the planet, is not so dense as the rest, and consequently it reflects less light, which gives it a dark appearance. When the plane of the rings is towards the earth they appear as a thin line or streak of light (Fig. 189), hence they can be of no great thickness. They are regarded as swarms of small solid bodies, or satellites, revolving in their orbits not far removed from one another. Like Jupiter in another respect, Saturn is thought to consist of dense gas or vapor but little removed from incandescence, and surrounded by a thick atmosphere which the telescope cannot penetrate.

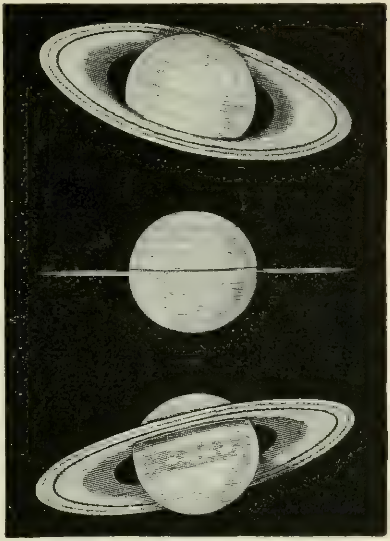


Fig. 189. Saturn in different positions in its orbit.

URANUS AND NEPTUNE. These two planets were not known to the ancients. Their distances are too great to allow a study of their physical features to be made with any degree of minuteness. The spectroscope indicates the presence of dense atmospheres quite unlike ours. They are probably gaseous bodies, but more nearly solid than Jupiter and Saturn. Their satellites are remarkable, in that their orbits, unlike those of the satellites of the other planets, are not at all in the plane of the ecliptic.

NAME.	Mean Distance from Sun in Millions of Miles.	Revolutions around Sun in Solar Days.	Diameter in Miles.	Time of Rotation on Axis.	Density water=1	Satellites.
				Days.		
Mercury....	36	88	3030	88	6.3	
Venus......	67	224.7	7700	224.7	4.8	
				Hrs. Min.		
Earth......	93	365.25	7918	23 56	5.6	1
Mars	141	687	4230	24 37	4	2
Asteroids ..	250	3 to 8 years	20-300			
Jupiter	482	12 "	88300	9 55	1.3	5
Saturn	884	30 "	73700	10 14	.7	9
Uranus	1780	84 "	32000		1.2	4
Neptune ...	2780	165 "	35000		1.1	1

COMETS AND METEORS.

Besides the well-regulated members of the solar system just considered, there are certain aberrant bodies which appear suddenly in the heavens, shine for a time with a greater or less degree of luminosity, and then disappear from view, in some cases never to return, in others to come back after intervals varying from a few years to many centuries. These are known as comets and meteors.

COMETS. These are aggregations of finely divided particles of meteoric matter. The brightest and densest part is called the head, and the flowing train that usually extends away from it, the tail; in some cases the tail is absent. When present it is always turned away from the sun, whether the comet is approaching that body or passing away from it. As the comet approaches the sun its velocity becomes very great, and the tail increases enormously in size, to be followed by a corresponding diminution as the comet recedes

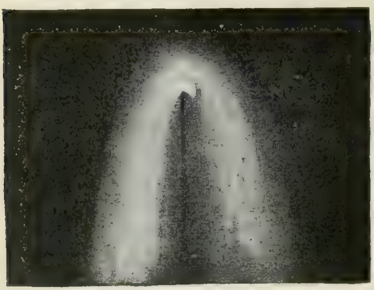


Fig. 190. Donati's Comet, 1858.

from the sun. The great comet of 1882, when in perihelion, threw out a tail over one hundred millions of miles in length. The head varies in size from a minute body scarcely visible through the telescope to one having a diameter greater than that of the sun itself.

Fig 191. Donati's Comet, 1858.

Notwithstanding the great size of some comets, their mass, or the quantity of matter in them, is exceedingly small. It is probable that the only appreciable effect on a planet coming into collision with the average comet would be a bright shower of meteors. Stars have been seen through the densest parts of comets without suffering any diminution in lustre.

ORBITS OF COMETS. Comets sweep around the sun in exceedingly elongated orbits, some of which are ellipses, but most of them take the form of a parabola, or of an open curve very similar to the parabola. This explains why they are visible for so short a time, for when they have passed around the sun their course, if elliptical, takes them, as a rule, far out of the earth's orbit, and if parabolic, it may take them away from the solar system for ever. Comets having elliptical orbits are divided into *short period* comets with revolution periods of less than 100 years, and *long period* comets with revolution periods exceeding 100 years. The comet of 1843 has a period of 100,000 years.

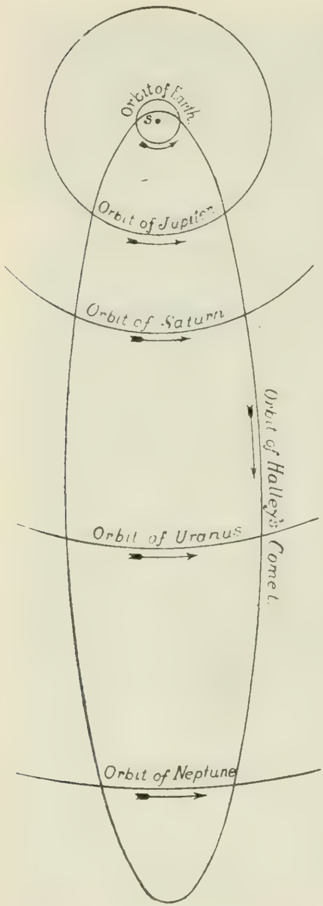


Fig. 192. Orbit of Halley's Comet.

In cases where it passes near enough to a planet, a comet may be so affected as to change its orbit from an open curve to a closed curve or ellipse. It will then return tó perihelion after a certain period, and its aphelion will be near the orbit of the planet accountable for the change of course. Halley's comet, whose orbit is shown in Fig. 192, was the first of these arrested comets whose return was noticed. Its period is 76 years, and it is due at perihelion again in 1911. It was captured and converted into a permanent member of the solar system by the planet Neptune. Jupiter, owing to

his great mass, has a large family of captured comets to his credit. Our own planet is believed to have assumed charge of nine.

The planes in which comets move are most erratic, and are inclined at all possible angles to the plane of the ecliptic. Some move around the sun in the same direction as the planets, and others move in a contrary direction.

METEORS. Everyone is familiar with the ordinary meteor, or "shooting star." It appears suddenly, as if a star had left its place in the heavens, passes swiftly through the atmosphere for a second followed by a trail of light, and then "goes out." Shooting stars may be seen any clear night when the moon is not shining. They first

Fig. 193. Bolides, or Fire Balls, as seen through the telescope.

burst into view about 75 or 80 miles above the earth's surface and "go out" when they reach a distance of 40 or 50 miles from the surface.

Sometimes much more formidable ones, called "bolides," sweep over greater areas of the heavens and are attended by explosive phenomena. Such was probably the nature of that brilliant meteor which passed over western Ontario about 9 o'clock on the evening of July 5th, 1898. This meteor, or meteor-swarm, estimated to have had a diameter of almost half a mile, first burst into view over the county of Peterborough at a height of about 120 miles. It swept west over a course of 200 miles in less than 10 seconds, passed over Port Elgin at a height of about 15 miles, and apparently plunged into Lake Huron. In its passage

through the atmosphere it left a trail of flame and smoke, the remains of which could be seen for about 10 minutes, and, according to many observers, its flight was accompanied by a loud rushing noise.

NATURE OF METEORS. From the velocity with which a meteor enters the atmosphere, some 30 miles per second, it is evident that it comes from regions of space outside of the earth. As soon as it encounters our atmosphere its speed is checked. The friction produces a temperature 1,000 times greater than that of red heat, and soon vaporizes the material of which the meteor is composed. It is the vapor that forms the luminous train in the wake of the meteor.

Fig. 194. Meteorite, showing granules of iron.

If the meteor is of sufficient size to reach the earth before being completely converted into vapor, it is called a *meteorite*. Many of these bodies have been analyzed and have been found to contain a great number of different elements, iron, silicon and oxygen usually predominating, but no element has been found in any of them which is unknown on the earth.

Several examples are on record of showers of these having reached the earth, much to the consternation of the people in the vicinity where they fell. The earth is daily being bombarded with millions of projectiles which our atmosphere converts into harmless meteoric dust, that settles slowly to the ground. Were it not for the protection afforded by the atmosphere, living on the earth would on this account be rendered somewhat hazardous.

METEOR SHOWERS. All meteors, like comets, move in some kind of a course, with the sun as a focus. Meteor-swarms, with orbits similar to those of comets, are known, and *meteor showers* are due to the earth's orbit intersecting the orbit of a group of meteors; and thus the earth may encounter one of these swarms, and actually does so very many times every year.

Sometimes meteors, instead of being in swarms, are strung out along their orbit so as to form a procession, and every time the earth crosses the orbit of such a meteor stream there will occur a more or less brilliant display of these incandescent visitors. One very conspicuous shower, the Leonids, so called because they seem to come through the sky near the constellation Leo, occurs every 33 years. An interesting record of their occurrences, with this interval between them, extends back, though not without many breaks, for a period of one thousand years.

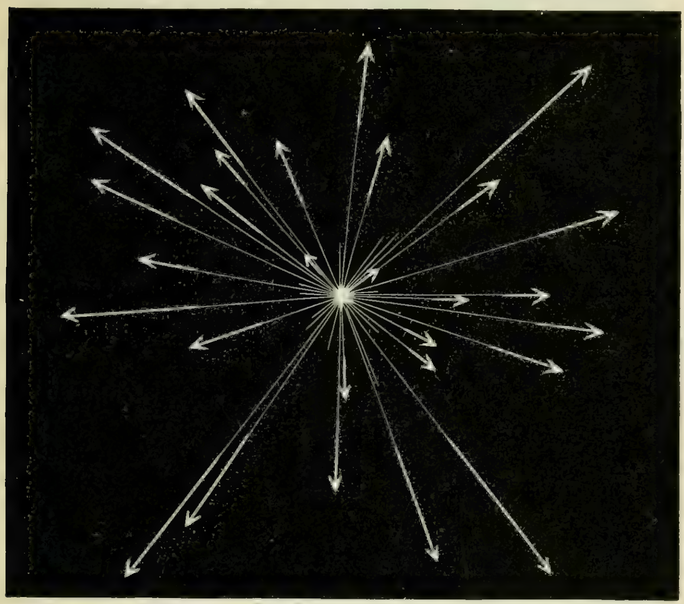


Fig. 195. A meteor shower.

ORIGIN OF METEORS. Several cases are known in which comets and meteors move in the same orbit, the comet often surrounded by the members of the meteor swarm. A case is on record of a comet breaking into fragments which increased their distances apart at each return to perihelion, and finally disappeared completely. Now it happens that the earth's orbit intersects the orbit in which this comet formerly revolved about the sun, and at this point

of intersection, the earth, after the disappearance of the comet, encountered a meteoric shower moving in the comet's orbit. These meteors are regarded as the remains of the disintegrated comet.

NEBULAE. In addition to the various classes of celestial bodies which have been described, the telescope shows the presence in space of thousands of patches of luminous matter the particles of which are very widely

Fig. 196. Irregular Nebula, with stars shining through it.

diffused. Some of these extend over a space many times greater than that occupied by the entire solar system. They resemble faintly glowing clouds, and hence are called *nebulæ*. Many astronomers regard them as masses of elementary gases at high temperature. Others believe them

to be swarms of meteorites at a low temperature, and that the particles of which they are composed are in continual collision with one another and thus produce heat sufficient to vaporize and render luminous a portion of their substance. They assume many different shapes as *irregular*, *spiral*, *annular*, etc. They are looked upon as the raw material out of which stars and planets are made.

NEBULAR HYPOTHESIS. In studying the solar system as a whole, one cannot but be struck with the symmetry and concord exhibited in the arrangement and movements of its various members.

Each planet is about double the distance of the preceding one from the sun.

They all revolve around the sun in the same direction, and nearly in the same plane.

Their orbits are all nearly circular. They all rotate on their axes in the same direction.

The satellites, as a rule, revolve in the same direction as the primary planets. This remarkable uniformity cannot be a mere coincidence, the result of accident. Viewed as a question in probabilities, the chances against such being the case are as 4,000,000 to 1.

Fig. 197. Spiral Nebula.

Towards the end of the eighteenth century the French astronomer, La Place, gave to the world his great *Nebular*

Hypothesis by which he attempted to account for the origin of the solar system. He supposed that in the remote past the sun and planets existed as a single nebula of intensely heated gaseous matter, which then occupied a space greater than that now included within the orbit of Neptune. A cooling and contracting process set in, and the nebular mass acquired a whirling motion. By gravitation amongst its particles, contraction toward the centre continued, and the velocity of rotation increased until the centrifugal force, overcoming the force of gravity, gaseous rings were thrown off from the outer edge of the mass. These eventually condensed and formed the various planets, the central portion remaining to form the sun in which the contracting and condensing process is still going on. Some of the planets in turn threw off smaller rings which formed secondary planets or satellites. In the case of Saturn, some of these rings still persist. Of the planets, those farthest from the sun are looked upon as the first formed. The physical condition of each planet will depend, in a great measure, on the extent to which it has cooled. Jupiter and Saturn are probably but little removed from a state of incandescence; the earth and possibly Mars give out very little heat, while the moon represents, as far as known, the most advanced stage in the cooling process.

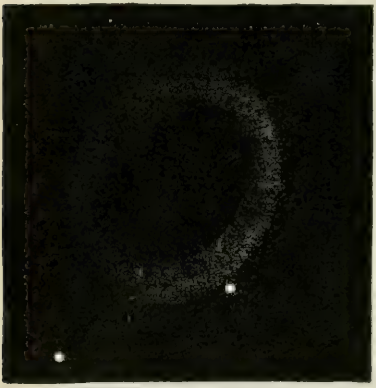


Fig. 198. Annular Nebula.

METEORIC HYPOTHESIS. As a result of careful experiments with the spectra of meteorites, and a comparison of these with the spectra of comets and nebulæ, Professor Lockyer regards all the bodies in the universe, including the fixed stars, the sun, and all the planets, as well as comets and meteors, as collections of meteoric matter in different stages of development. According to this view a nebula of widely diffused meteoric dust at a low temperature is the earliest stage in the life history of a star. Under the influence of gravita-

tion amongst its particles a condensation and compression of its mass takes place and the temperature gradually rises to a maximum, as seen in the hottest and whitest stars, such as Vega and Sirius. From this stage of greatest heat and light, there is a slow and gradual diminution in temperature through the yellow stage, of which Pollux and our sun are examples, to the red stage, represented by such a star as Hercules, and finally to dark, or non-luminous bodies, such as the planets of our solar system.

CHAPTER X.

COMMERCIAL GEOGRAPHY.

Different parts of the earth have different climates, different soils, different natural products, and are inhabited by peoples of widely different characteristics and modes of living.

Some parts of the earth are much more thickly inhabited than others; people who live in cities are chiefly engaged in manufactures of various kinds, while those inhabiting rural districts are usually employed in agricultural pursuits, producing the raw materials as cotton, wool, and food-stuffs, which make manufacturing industries possible.

People who produce the raw materials have to be provided with manufactured articles,—clothing, implements of various kinds, furniture, etc. The manufacturers require the materials out of which to make these articles, while food-stuffs are needed by all. No country produces all the necessaries, conveniences, and luxuries of life. Each is dependent upon some other for the supply of such of these articles as are not produced within its own borders. Cotton, for example, will not grow in Canada; hence the cotton mills of Ontario, Quebec, and New Brunswick are dependent upon countries which do grow cotton for a supply of the raw material that is to be spun into yarn and woven into cloth.

CONDITIONS AFFECTING COMMERCE.

The exchange of the commodities of one country for those of another gives rise to *commerce*. From a consideration of the articles of exchange, the routes of trade, the centres of production and distribution, the facilities for such distribution, the influences which stimulate trade or retard it, etc., arises *Commercial, or Economic, Geography*.

In primitive times, each family or community attempted to produce all the things necessary for its own existence; but the increase of population, along with greater

facilities for intercourse between different countries, has tended to make each community devote its attention to what it can most profitably produce, and exchange its commodities for those of other communities. The mutual exchange of products gives rise to *Trade* and *Commerce*.

In theory it is the *surplus* products of one country that are exchanged for the surplus products of another. But with modern enterprise, and through the use of money, the conditions affecting commerce have been so changed that now many articles are produced almost exclusively for export. It is with this end in view that the sugar-planters of the West Indies and the cotton-farmers of Egypt produce their crops. It is found that the raw materials can be more profitably manufactured into the finished product in Great Britain, than where they are produced.

DISTANCE. In the case of articles of large bulk, as coal or wheat, *distance* may make it impossible to carry on a profitable trade. The coal of Nova Scotia cannot be used profitably west of Montreal on account of the cost of transportation. The Province of Ontario requires large quantities of soft coal for its factories, but the use of Nova Scotia coal would so increase the cost of manufacture that it would be impossible for an article to compete in the markets with a similar one produced where fuel is cheaper. In this instance Ontario has to depend upon a foreign country for a supply of soft coal, it being cheaper to import coal from Pennsylvania and Ohio, even with a duty of fifty-three cents per ton, than to bring it from Nova Scotia.

Edmonton, owing to its distance from large centres of population, finds it more profitable to grind the wheat grown in that region into flour and send it to British Columbia than to ship the wheat.

MEANS OF TRANSPORTATION. The means of transportation have much to do in determining the nature of the commerce carried on. On land these consist in parts of Africa and Asia, of porters; in the extreme north, of dogs and dog-trains; in the deserts of Africa and Asia, of pack animals as the camel; in the mountainous parts of South America, of the horse and llama; and in America and Europe, of railroads. On rivers and canals

boats are employed, and either steam or sailing vessels on larger bodies of water. A little consideration will reveal how the means of transportation must greatly affect the nature of the commodities produced. It is impossible to convey large, heavy articles far without the aid of waterways or railroads. Without such aid, it would be impossible to convey the lumber of the Ottawa valley to a profitable market, and without railroads there would be little wheat raised in the North-West Territories.

CLIMATE. The productions of a country, and hence the nature of its commerce, are largely dependent upon its climate. Sugar-cane, cotton, Indian corn, and coffee cannot be grown in every part of the world, and though wheat and cattle are found almost everywhere, yet some climates are better adapted to their production than are others.

The productions of a country are far more influenced by its climate than by its soil. Many parts of the deserts of Africa and Asia require only a greater rainfall to make them fertile. The oases show how fertile the soil becomes when there is sufficient moisture to support vegetation. The arctic regions are destitute of vegetation of commercial value owing to low temperature rather than to barrenness of the soil. Thibet requires only a higher temperature to make it teem with vegetation.

Then, too, the rigors of winter in cold-temperate climates often interfere with commerce. The St. Lawrence River is closed to navigation for several months every year. The ports of the Baltic are ice-bound every winter. Hence, commerce, for the time being, must find its way by other routes. Thus the vessels which call at the ports of Montreal and Quebec when the River St. Lawrence is open, seek the harbors of Halifax, St. John, or Portland during winter months. In summer the Great Lakes of North America are frequented by merchant-vessels, but on the approach of winter these waters are deserted, and the boats are securely laid up in some port to await the return of spring. Hence during the winter season other means of transportation than boats must be used.

LABOR. So long as each laborer finished his own article in every part, so long were commodities dear and commerce small. But with the division of labor and the introduction of machinery, thousands of articles can be produced in many cases for what one formerly cost. Thus comparatively little cotton was worn so long as it was spun only by women in their homes, and woven into cloth on hand-looms; but with the introduction of the spinning

jenny, and subsequently of the spinning mule and the cotton gin, the cloth was manufactured so cheaply that every one could buy it. In this way cotton has become one of the most important articles of commerce. In growing the raw material, in manufacturing it, and in distributing the finished product to all parts of the world, millions of money are invested, and employment is given to vast numbers of workmen.

Some articles require much labor to prepare them for use. These can be produced only where labor is so plentiful, and hence so cheap, that a profit may result to the producer. Thus both the soil and the climate of parts of the United States of America are adapted to the growing of the tea-plant, but labor is so dear that tea grown in the United States cannot compete in the markets of the world with that grown in China, Japan, or India. However, cheapness of labor is not the only determining factor in the profitable production of an article. A workman may be paid only a dollar a day, and produce only two dollars worth of goods; whereas another with machinery to enable him to work to advantage, may receive two dollars a day and produce ten dollars worth of goods. In the markets of the world, the former cannot compete with the latter.

Trades unions, by limiting the hours of work and the amount and kind of work a member may perform, and by fixing a higher scale of wages, tend to affect the cost of production of commodities of commerce.

GOVERNMENT. Government has much to do with fostering or crippling trade and industry. Where property is secure and life safe, capital will seek investment, and manufacturing and other enterprises will flourish; but where the government is weak, and revolutions are common, the insecurity of life and property repels capital and checks enterprise.

A good government has many ways of fostering commerce. It improves harbors, constructs canals and locks to overcome natural obstacles in the waterways, erects lighthouses, charts the coast and places buoys to warn mariners of hidden reefs and dangerous shallows, and collects and distributes information of great value to farmers and manufacturers. In addition to these it also provides officials called *consuls*, who reside at all the large centres of commerce, and whose

duty it is to watch over the commercial and other interests of the country they represent, and to keep their government informed of all movements that may affect the home country.

DUTIES. Most countries impose taxes called *duties* on goods coming into the country. The government is thus enabled to raise a revenue to carry on the affairs of the country. As duties are usually levied on manufactured articles and not on raw material, many hold that they serve the additional purpose of protecting the home manufacturer against foreign competition. By a system of protective duties, the government of the United States has fostered home manufactures and home productions, and has thereby, it is held, made the United States one of the greatest manufacturing and producing countries of the world.

In Canada, home industries are protected by admitting raw materials free of duty and by imposing a duty on imported manufactured articles. Such machinery however as cannot yet be profitably made in Canada, and is required for carrying on manufacturing, mining, and other industries, is also admitted duty free

At times it is found expedient to impose a tax on commodities, usually raw materials, going out of the country. The tendency of this is to compel the conversion of the raw material into the manufactured article in the country producing it. This gives employment to many workmen, and the home country thus reaps the benefit of increased enterprise and population. It is for this reason that an export duty has been placed on saw-logs in Ontario. As a result many sawmills are now busy on the north shore of Lake Huron producing lumber which is largely consumed in the United States, while the sawmills of Michigan are idle owing to the lack of logs.

RELIGION AND CUSTOM. Commerce is also affected by the customs of the people. Thus, the inhabitants of the British Islands prefer black teas while Americans select green ; hence, black tea is largely taken to Great Britain, and green to the United States and Canada.

Even religious customs affect commerce. Little fermented liquor is imported into Mohammedan countries because its use is forbidden by their religion. Since the inhabitants of the Sudan have become Mohammedans, a great demand has arisen for white cottons there.

In proportion to their population, countries in which the prevailing religion is Roman or Greek Catholic, consume the largest quantities of fish. The fish taken in the waters of the north of Europe are largely exported to the south and centre of Europe, and Canadian fishermen find a ready market for their salted cod and other fish in the West Indies and the countries of Europe.

DISTRIBUTION OF COAL AND MINERALS.

Coal and iron are so closely connected with manufactures of all kinds, the one supplying the energy and the other the machinery, that, without them, it is difficult at the present day for manufactures to thrive. But these two commodities are so bulky that their transportation is costly, and hence, unless the two are found associated together or in close proximity, the manufacture of iron and steel goods must remain backward; for the coal is used in smelting the iron ore, the iron is converted into steel, which in turn is converted into steel products. The occurrence of these two minerals so closely together in Belgium, in Lancashire, and in Pennsylvania, is the reason for the great commercial activity which marks these centres.

In the early days of the cotton industry in England, water was the great motive power, steam not having yet come into use; hence places abounding in waterfalls were sought for as the sites of factories. Lancashire has an abundant rainfall, its streams are short and rapid, and so factories sprang up everywhere. With the invention of the steam engine, a new motive power took the place of water. But in Lancashire coal and iron were found together. The cotton industry, therefore, continued in Lancashire, the only change being the removal of the factories from the banks of the stream to the crowded cities.

WARS AND PERSECUTIONS.

Wars and persecutions affect trade and commerce in various ways. Sometimes they compel the emigration of skilled labor, as in the case of the Flemish weavers whom Edward III. in 1337 induced to settle in England owing to the disturbed condition of their own country. In the time of Elizabeth, the persecutions of the Duke of Alva drove other Flemish emigrants to England. This caused a great decline in the Flemish woollen industries and a corresponding growth of those of England, for the refugees brought with them the knowledge of the manufacture of the finer qualities of cloth, and enabled their adopted country to secure a pre-eminence in this industry which it has maintained ever since.

In 1685 the revocation of the Edict of Nantes by Louis XIV. caused many Huguenots to flee to England. These exerted a remarkable influence on the growth of the silk industry as well as on the manufacture of linen, on calico printing, and on the production of sail-cloths and paper.

During the war between the Northern and Southern States in 1861-1865, the American supply of cotton for the mills of Lancashire was

stopped. British merchants then looked to India for a supply. This induced the farmers of India to increase their production of cotton, the black basaltic soil north of Bombay being particularly adapted to growing it. When the war was ended, the demand for Indian cotton fell off. This caused the Indian planters to begin its manufacture on the spot. Cotton manufacture has so greatly increased in India that Bombay has now become a great cotton market. Labor is so cheap that the Bombay merchant can readily undersell his British competitor in the markets of China and Japan. This new Bombay industry has greatly affected Lancashire.

AIDS TO COMMERCE.

TRANSPORTATION. The most important aid to commerce is facility of transportation. Before railroads were constructed, commerce was necessarily confined to the interchange of articles which could be transported on the backs of animals, or carried comparatively short distances in boats from one place to another on the same river, lake, or sea, as in the case of cities on the Mediterranean.

The discovery of the New World and of a sea-way to India round the Cape of Good Hope, rendered it necessary to build larger boats, and so commodities were carried farther afield. At first ships were propelled by the wind, but with the advent of the steam engine, the sailing vessel has gradually given place to the steamship with a capacity of many thousand tons, and a speed of from fifteen to twenty miles an hour more.

Transport by water is usually cheaper than by land. Thus in 1903 it cost 12 cents to carry a bushel of wheat by rail from Regina to Fort William, a distance of 780 miles, and only 2½ cents to carry it by water from Fort William to Midland, a distance of about 500 miles; it cost 5 to 6 cents a bushel to carry a cargo of wheat from Fort William to Montreal by water, a distance of 1,224 miles. In the east, where rates are lower, it cost 5½ cents per bushel to carry wheat by rail from Midland to Portland, a distance of 685 miles.

The cost of loading and unloading goods is a very considerable item in the cost of transportation. Every time goods have to be handled before reaching their destination the cost of carriage is increased, hence every possible means is taken to avoid transhipment.

CANALS. Rivers are the natural means of communication; but these may be rendered useless except for short distances, by the presence of rapids or waterfalls; or where

they form flood plains their course may be so winding that very long distances have to be traversed by boats in order to make a very short direct advance ; or there may be no rivers where the needs of commerce require them; and finally a country may be in the form of a peninsula so that a long circuitous sea-voyage is necessary in order to pass from a port on one side to a port on the other, the two places being, possibly, only a few miles apart in a direct line.

Artificial streams, or *canals*, overcome these disadvantages. The fine series of canals from Sault Ste. Marie to Lachine renders the St. Lawrence a waterway even for ocean-going craft, for two thousand miles into the heart of the continent; the Suez canal shortens the distance from England to India by over 5,000 miles, and thereby enables India to send wheat to England,—an impossibility before the canal was built except with injury to the grain from heating on the long voyage ; the Erie canal makes a waterway from Lake Erie to Albany where nature had practically supplied none ; the Manchester ship canal enables the manufacturers to load and unload goods at their very doors without the need of transporting them by rail to or from Liverpool or any other sea-port ; the Kiel canal gives a short route to the trade of the Baltic with the North Sea ; and China has, among hundreds of others, its great Imperial canal, the longest in the world. These artificial rivers are multitudinous ; no civilized country is without them.

STEAMSHIPS. Steamships have greatly aided commerce, not only by rendering the mariner practically independent of wind and current, and thus shortening the time of the voyage, but also by carrying cargoes many times larger than the sailing vessels can. They have given, too, a regularity to navigation which was unknown in the old days of sailing vessels. Not only is the time of sailing fixed but the time of arrival also. With sailing vessels the time of arrival could only be conjectured.

In 1838, the *Sirius* and *Great Western* began to ply regularly across the Atlantic, and were the first actual "liners." In 1850 the average time of crossing was 13 days ; in 1860 it was 11 days ; in 1870 it was 9 days ; in 1880, 8 days ; and since the advent of the "Ocean Greyhounds,"

the voyage between Sandy Hook and Queenstown has been made in less than $5\frac{1}{2}$ days.

Improvements in the furnace, boiler, and engine have reduced the cost of steam power nearly one-half during the past 25 years. A pound of coal, by improved appliances, now produces three times as much steam as it did a quarter of a century ago. The employment of donkey-engines in loading and unloading cargoes, hoisting sails and heaving anchors, also saves much time and labor.

Since iron and steel have displaced wood in shipbuilding, vessels have been greatly enlarged; instead of vessels of a few hundred tons,* vessels of 5,000 to 10,000 tons are becoming common. The Oceanic, which was launched in 1899, has a capacity of 17,000 tons; the Kaiser Wilhelm II. has a displacement of 26,000 tons; the Cedric of 37,800 tons.

A steamship will carry four times as much cargo during the year as a sailing vessel of the same tonnage, for it can make four voyages to one of the sailing vessel.

The reduction of the time of the voyage, of the cost of loading, unloading, and manning vessels, and the employment of vessels of greater capacity, have greatly reduced the cost of transportation and hence have lessened the price of the goods themselves and extended their use. A demand has thus been created for larger quantities. Hence the producer and the consumer are both benefited. It is now possible to ship wheat grown on the plains of Manitoba to Liverpool and sell it profitably at a price which prevents competition from the home product grown on the high-priced lands of the old world; and it is under these favorable conditions that the cattle trade has grown up between Canada and Great Britain.

The increased size of the vessel and the reduced time of the voyage have made cold storage possible. Hence perishable goods of all kinds, as fruits and meats, can be readily transported, even across the torrid zone, and yet reach their destination in good condition. In this way it is coming to pass that the people of the north, during their winter, enjoy the luxury of eating fruit which was grown in Cape Colony or Australia.

HIGHWAYS. In every civilized community good roads are now esteemed essential to the general prosperity of the country. Over these the farmer draws his produce to a ready market, and the market gardener carts his vegetables to add to the comfort of the dweller in the city.

* In measuring ships a "ton" means 100 cubic feet of space.

Good roads bring communities together, and make social intercourse in rural places possible. Without good roads a farmer will be unable to see the advantage of working hard to raise produce which he cannot exchange for something to add to his comfort and convenience; and so he will raise only the bare necessaries of life.

In countries such as China, which is content with poor roads and paths along which wheelbarrows are trundled, or where human porters or pack animals are the means of transport, freightage is dear and transportation slow. In the west of China it costs about 25 cents to haul a ton one mile; on the great lines of railroad in North America it is about 6 mills. Then on account of the slowness of transportation, plenty may reign in one part of the Chinese Empire and thousands of people be dying of famine in another.

In Asia and North Africa trade is still carried on over the same routes that were followed thousands of years ago. These routes are not roads in the proper acceptation of the term; they are merely tracks. However, even in Asia, the importance of good roads is realized, and the government of India has recently constructed a great highway from Calcutta to the borders of Afghanistan. It was under the guidance of Macadam and Telford that road-making became a modern art about the beginning of last century. Since that time all enterprising countries have constructed roads to connect all important places with one another. Over these, raw materials of commerce are brought to market and gathered into centres for distribution or export. Before the advent of the railroad, places in the interior had to rely entirely on common roads for transportation.

RAILROADS. The enterprise of western nations both in Europe and America has spanned their continents with railroads. Great systems of railways now connect all important places.

When our country was first settled, it was along the banks of the great rivers and the margins of the lakes that men made homes for themselves; but now distance from waterways is no drawback, for the railway follows the settler into the interior and brings his products to market however far away the market may be.

In recent years railroads have largely superseded both roads and waterways for internal communication. Reasons for this are easily found. Rapidity of transport, promptness of delivery, and cheapness of carriage, are essential to the success of many kinds of business. All these advantages are secured by the railroad.

Before a railroad was constructed on the lower Congo, thereby overcoming the rapids and falls upon this part of the river, many thousands of native porters carried freight round the cataracts in small loads of from 60 to 80 pounds each at a cost of $200 per ton. The journey occupied three weeks. The railway does this work far better in two days at one-tenth the cost. In America the charges on trunk lines of railways amount to about 6 mills per ton per mile. It is this cheap rate which makes it possible for the wheat and cattle of the North-West to be transported to the sea coast at a cost which enables the producer to realize a handsome profit.

Modern enterprise is almost entirely dependent upon the railroad. Without it the wheat and the cattle could not be transported from the interior of this continent to the sea-board ; had it not been for the railroad it would have been impossible to provision and maintain the British forces in the recent war in South Africa; and General Kitchener could not have penetrated the continent to Khartum and defeated the Mahdists at Omdurman, for as the army advanced the railroad followed over the desert and brought to the front supplies, without which no army can move. In the Crimean war, it was not until a railway was constructed from the port of Balaclava to the trenches, that supplies could be furnished to the allied troops in quantities to keep them in comfort.

In constructing a railway we burrow under mountain and river, bridge streams and arms of the sea, span frightful chasms, and lay firm roads across quaking bogs.

The St. Gotthardt, the Mont Cenis, and the Simplon tunnels pierce the Alps, the Hoosatonic dips under the Alleghanies, and many a smaller but needful one lies along the line of the Canadian Pacific and other railways that cross the western mountains. The Victoria and other magnificent bridges cross the St. Lawrence, still others stretch from side to side of the Niagara gorge, while among the western mountains the eye falters to look down into the frightful chasms from the giddy ledges and shelfs of rock along which the track winds its way.

Our *Canadian Pacific Railway* spans the continent from St. John to Vancouver, a distance of 3,387 miles, and shortens the journey from Liverpool to China by 1,000 miles. The *Grand Trunk Railway* extends from Portland through Quebec and Ontario to Chicago, a distance of 1,138 miles, crossing to the United States beneath the St. Clair River in a huge iron tube 6,026 feet long. The Grand Trunk company is to build (1903) a transcontinental railway from Moncton to Port Simpson on the Pacific, passing some distance north of the Canadian Pacific Railway. The *Canadian Northern Railway* company is also building (1903) another railway that aims at reaching the Pacific. The *Intercolonial Railway*, planned as a necessity and a sign of union when the different Provinces united to form the Dominion of Canada, reaches from Halifax and St. John to Montreal by the way of Moncton and Rivière du Loup.

In the United States the great transcontinental railways are the *Union and Central Pacific* from Chicago to San Francisco ; the *Great Northern* just south of the boundary, from Duluth to

Seattle; the *Northern Pacific* to the south of the preceding, from Duluth to Portland, Oregon; the *Southern Pacific* from New Orleans to San Francisco; and the *Atchison, Topeka and Santa Fé* from Chicago to San Francisco.

MONEY. In barbarous or semi-civilized countries the most primitive form of trade is the *bartering* of commodities. In the early days of Canada, the Indians bartered their furs for guns, gunpowder and blankets. But no extensive trade can be carried on without some medium of exchange—something which sellers willingly receive for their goods, because they know they can get with it articles which they need. This medium of exchange is *money*.

Money usually consists of gold, silver, and copper, for these are easily preserved and readily transported; but any medium of exchange is money. Thus in the Sudan to-day, cowry shells are used as money; in other parts of Africa cattle serve as the medium of exchange and thus become money. An African chief to-day pays so many cattle for his wife. In the early days of England, slaves and cattle were money. This was called *living money* to distinguish it from gold and silver, which was called *dead money*. It is from the use of cattle (Lat. *pecus*) as money that the Romans derived their word for money, *pecunia;* and the word "fee" is only the Old English "feoh," cattle. In the early days of Newfoundland, codfish served as the medium of exchange.

BILLS OF EXCHANGE. In countries which carry on considerable trade with each other, the debts due from one to the other are generally about equal. In Canada, for instance, there are always a number of persons indebted to others in Great Britain for books, manufactures of wool, furs, hats, &c., which are imported, and likewise a number in Great Britain indebted to others in Canada for wheat, flour, fish, lumber, &c., which are exported. Now instead of sending coin from Canada to pay the debts in Great Britain and from Great Britain to pay those in Canada, *Bills of Exchange* are used to settle the debts reciprocally due between the two countries.

Thus suppose A in Toronto buys goods to the value of $1000 from B in Manchester, England, and C in London, England, buys $1000 worth of goods from D in Montreal. Through the intervention of a bank and by means of a Bill of Exchange, A is directed to pay to D $1000 and similarly C is directed to pay B. Thus the debts are cancelled.

The Bill of Exchange makes unnecessary the transmission of coin or specie twice, and prevents the loss of interest

during the time of transmission as well as the risk and expense of transportation. It is only when one country buys much more from another than the latter does from it that an actual transmission of money is necessary. In this case the *balance of trade* is said to be against the country making the larger purchases.

BANKS. Banks aid commerce in many ways. They lend money and thus enable enterprises to be prosecuted which could not otherwise be carried on. They circulate bank notes which are far more convenient for carriage than coin. They afford a safe and ready treasury in which the merchant may deposit his cash each day. Providing he has sufficient money in a bank the merchant may pay his debts by drawing cheques on the banks: he need not handle the money. Banks, too, enable a debtor in one place to pay his debts in another by buying a bank draft if the seller of the commodity lives in the same country as the debtor or a bill of exchange if they live in different countries.

ELECTRICITY, TELEGRAPH, TELEPHONE. The electric telegraph now connects all places of importance. There is scarcely a village to which messages cannot be sent by its means. Submarine cables enable one country to communicate with another without delay, and thus, an important event happening anywhere is soon known throughout the civilized world.

Important places are also connected by telephone wires, so that it is possible to talk to another hundreds of miles away.

All these by aiding rapid communication affect trade. The merchant gives his order, as it were, to-day and has his wants supplied to-morrow; there is, therefore, no necessity for keeping large stocks of goods on hand. Then without the telegraph it would be impossible to move trains with the same safety and despatch as at present. Wireless telegraphy may furnish another means of communication, and may affect the cost of sending messages, lines of telegraph or ocean cables not being needed.

Electric power is now generated at some convenient place—where there is water-power—and transmitted over wires to places many miles away. It is used to drive machinery, move electric cars, run trains, light streets, &c. Owing to the simplicity of its application, the absence of smoke and dust, and the freedom from danger of fire or explosion, electric power is displacing steam as a motive power.

POSTAL SERVICE. The postal service supplies a somewhat slower but a far cheaper way of communication than the telegraph does by providing for the quick, safe, and cheap transmission of letters, post-cards, newspapers, parcels, and money orders. By the certainty and despatch with which it discharges its various duties, the postal service renders an incalculable service to trade and commerce.

HARBORS AND DOCKS. Good harbors are necessary wherever sea trade is extensive. On both sea and lake vessels require sheltered places where they may load and unload their cargoes with safety. Some places are protected by their position from the violence of storms as the harbor of Vancouver on Burrard Inlet, of Toronto on Lake Ontario, of Halifax on an inlet of the Atlantic. Other places have been made into good harbors by the construction of breakwaters as that of Algiers. Still others, though sheltered from storms, are not deep enough to receive ocean-going vessels, and have to be deepened. Large vessels require a depth of water from 25 to 35 feet. Thus the harbor of Montreal and its approach through Lake St. Peter had to be dredged. The Clyde, a small stream, was deepened and widened to allow the largest ocean steamers to reach Glasgow.

In addition to deepening the harbor, docks and wharfs must be built to allow the vessel to load and unload its cargo with ease and despatch. At Glasgow 3 miles of docks have been constructed; at Liverpool over 7 miles; at London 30 miles. But most of the great centres of commerce are situated on large, safe, natural harbors.

OTHER AIDS. Express companies, by facilitating the safe and expeditious carriage and delivery of articles which require careful handling, by delivering an article and at the same time collecting its price (C.O.D.), and by issuing express orders for money and thus becoming a safe and chief transmitter of money, greatly aid commerce.

A uniform system of weights and measures such as the metric system would aid commerce, by giving all nations the same system of measures and thereby facilitating computations.

CENTRES OF COMMERCE.

Most interesting is the question why the great centres of population and commerce are located where they are, and why one place is prosperous and rapidly increasing in population while another is declining. Many considerations enter into this question.

DEFENCE. As centres of population are generally centres of trade and commerce, in early times when men were lawless and fighting was common, facility for defence was an important consideration in selecting a site convenient for carrying on trade with neighboring tribes.

The Acropolis, or "upper city," at Athens was a natural fortress. The Castle Rock of Edinburgh, in addition to giving a wide view, supplied an easy means of defence. The original London was founded on the first high ground met with in coming up the Thames. Merchants who desired to penetrate inland naturally found a resting place here from which they could ply their trade with the surrounding tribes; but it was also admirably adapted for defence. The lagoons of the Lea and the Thames protected it on the east and south. The high banks of the Fleet protected it on the west and a broad fen stretching along the north side of the hill forbade easy access from the north.

Paris, the capital of France, was originally built on a small island in the Seine between the upper and lower navigation of this stream. Its central position in the midst of a great plain gave it ample facilities for commerce.

Venice, the pile-built city, stands on many islands. It was founded by a people who, terrified by Attila and his Huns, built for themselves homes where they were safe from such barbarians. Its admirable position for defence enabled it to resist attacks from the land side, and situated between the east and the west, between the Byzantine and Lombard realms, each needing what the other could supply, her ships began to swarm over the Adriatic at a time when the Mediterranean was almost the navigable world.

The site of Quebec which was occupied by the village of Stadacona, was, no doubt, selected both by the Indians and by the French with a view of easily repulsing any attack from enemies. It was originally on the tongue of land between the St. Charles and St. Lawrence Rivers. The French saw also its great natural advantages for commerce. It has a fine harbor, deep enough to float the largest vessels, and until the river was deepened so that ocean vessels could reach Montreal, it was the port of unloading and loading of all large ocean-going vessels.

The insular position of Montreal afforded a natural means of defence. Its position at the head of navigation in the St. Lawrence River caused it to become the great distributing centre for the west and north-west and Montreal has grown to be the commercial metropolis of Canada.

The old fort, erected in the angle of the Assiniboine and Red Rivers, marks the position of the City of Winnipeg. The men of the old North-west Company who founded this fort, considered not only its convenience for prosecuting the fur trade with the Indians of the North-west, but also had a keen eye for defence against any possible attacks from their enemies. Edmonton, in a bend of the North Saskatchewan, is admirably placed both for defence and as a rendezvous for the fur trade.

FAVORABLE POSITION. On examining other centres of trade and commerce—as New York, New Orleans, Philadelphia, Chicago and Halifax in the New World, and Liverpool, Marseilles, Bourdeaux in the Old, we find that some circumstance of favorable position, so that commodities might be cheaply manufactured or readily exchanged, had much to do in determining their sites and subsequent growth. Such cities were built at places easily accessible and generally near sources of natural wealth.

New York owes its preëminence in the commercial world on this continent to its being at the mouth of the only waterway in the United States leading into the interior from the Atlantic coast. It is situated on a long, narrow tongue of land, which projects into a deep bay. Its favorable position for commerce and the subsequent construction of the Erie Canal, gave such an impetus to its growth that it is now the second city in the world as regards population. Nearly one-half of the exports of the United States leave this port and two-thirds of the imports of that country enter through it.

The rapid deposition of sediment at the mouth of the Mississippi prevented a city from growing up there, and so New Orleans is situated 100 miles from the mouth of that natural outlet for the products of the great interior valley. Before the advent of the railway this port gave promise of becoming the greatest on the American continent. But the railways and the improvement of the navigation on the St. Lawrence have diverted much of the commerce eastward to New York, Boston and Montreal. Thus New Orleans furnishes a striking illustration of how the growth of a city may be affected by a change in the means of transportation of commodities.

The fact that the cost of transportation is less by sea than by land, and transhipment must be avoided where possible, has caused cities to spring up elsewhere than on the coast. These are, at times, at a considerable distance inland. Montreal, before the canals were built, was at the head of navigation on the River St. Lawrence. Being far inland, it became a great distributing centre and thus the foundation of its commercial prosperity was laid—a prosperity that it has continued to maintain notwithstanding the changed conditions of commerce.

Philadelphia, one of the great cities of the United States of America, at the head of a deep estuary, is 120 miles from the sea. It occupied a very central position in the early days of trade of that country. Commodities could be transported inland along the Delaware and Schuylkill rivers, obstacles to the navigation of which were overcome by canals. Thus Philadelphia became a great distributing centre for all the surrounding country. In addition to the advantages from its central position, the proximity of coal and iron has greatly helped to establish the city as a manufacturing centre.

HEAD OF NAVIGATION. Wherever transhipment of products was necessary, there a settlement grew up. Hence, at the head of navigation on all the great arteries of commerce, large centres of population are found. Many places such as Montreal, Fort William, Albany, Duluth, Minneapolis and Chicago received from this cause a great impetus to their growth. Vessels discharged their cargoes at these places and were laden with the products of the surrounding districts to be transported to other centres of industry.

CONFLUENCE OF RIVERS. In addition to rendering the defence of a place easy, the confluence of streams opens up a much more extensive area of country to which commodities may be distributed. This is one reason among others why such places as Winnipeg, Montreal, Three Rivers, Quebec, Ottawa, Cairo in the United States, St. Louis, Pittsburg, Lyons, have all become important centres of trade and commerce.

WATER POWER. Water power supplies a natural means of turning machinery. Hence, falls and rapids in streams were sought for and this natural energy turned to the convenience of man. In the early days of Canada flour and sawmills were located at these sources of power. Around these mills settlements grew up, some of which have become places of importance.

From this cause originated such places as Port Hope, Napanee, Bowmanville, Rat Portage, Sturgeon Falls, Ottawa, Pembroke, Fergus, Hawkesbury, Lindsay, Peterboro', and Almonte in Ontario, and St.

Stephen, Milltown, Hartland, Edmundston and Woodstock in New Brunswick.

CENTRAL POSITION. Other places owe their importance to their central position for collecting and distributing the commodities of the surrounding district.

Constantinople owes much of its growth and development to its favorable position. It is on the natural line of travel between the north and the south, between the east and the west. Moscow owes much of its importance to the same cause. There are no natural obstacles to prevent communication with it from the Volga, Oka, Don, Dnieper and Western Dwina Rivers. Vienna in addition to being at the head of navigation on the Upper Danube, is also centrally situated. In early times the roads from the east converged at Vienna before finding a common pass over the Alps. Berlin is situated in the centre of the great northern plain of Germany. Paris is in the centre of the great plain forming the northern half of France at the junction of the Marne with the greatest waterway in France. Beside being at the very head of inland navigation Chicago, among other causes, owes its great and rapid growth to its central position. The great plains to the south, west, and north supply such immense quantities of grain and cattle as to render Chicago the greatest food centre of the world. The central position of Winnipeg, Brandon, Regina, and Edmonton is, no doubt, the cause of the rapid growth of these places. Winnipeg is already a great railroad centre. Edmonton, situated at the northern terminus of the Calgary and Edmonton Railroad, is a centre for collecting the furs of the north, as well as a depot from which the adventurous traders of these regions may draw their supplies.

GREAT RIVER BENDS. When a river bends and assumes an entirely new direction as in the case of the Niger at Timbuktu, the Volga at Kazan, the Ohio at Cincinnati, and the Petitcodiac at Moncton (formerly called *The Bend*), there usually springs up a place of importance; for much of the freight reaching such a place is not destined for points in the new direction which the river takes and so transhipment becomes necessary.

THE PRESENCE OF NATURAL WEALTH. The abundance of such natural products as coal, iron ore, gold, salt, etc., is another cause of the origin of centres of industry. Our own land furnishes some striking examples. Sydney, in Nova Scotia, owes its importance to the abundance of coal and iron ore in its vicinity. A population of 2,427 in 1891 has become 17,746 in 1901 owing to the increased activity in the coal regions of Cape Breton. Its central position gives it an advantage over other centres in

distributing iron and steel. It is 1,200 miles nearer European ports than Baltimore, the port nearest to Pittsburg. It is 2,300 miles nearer Liverpool than is Pensacola, the port nearest to the great Alabama iron district. Owing to the fact that Rio Janeiro is far east of New Orleans, Sydney is 600 miles nearer it and Buenos Ayres than New Orleans is, and it is 900 miles nearer to Cape Town than the great southern sea port.

The abundance of spruce to supply pulp for paper, and of iron ore for steel, together with an unlimited supply of water-power has made Sault Ste. Marie a great hive of industry. Dawson, which had no existence a few years ago, has now (1902), a population of 9,142 owing to the discovery of gold in the Klondike. Rossland, unknown till recently, is now a flourishing mining town of some 7,000 inhabitants.

In South Africa, Kimberly owes its existence to its diamond mines, and Johannesburg to its gold mines.

The presence of natural products gives rise to manufacturing centres, especially if an abundant supply of coal for fuel is found in the immediate neighborhood. The development of the coal and iron mines of Pennsylvania has made Pittsburg one of the great centres of the world for producing iron and steel. The proximity of coal and iron mines has enabled Glasgow to become the greatest ship-building centre of the world. The abundance of coal and iron deposits in its vicinity caused Birmingham to take first place in the industrial world as a hardware manufacturing centre. The rearing of the silkworm in the south of France supplied the raw material which the looms of Lyons converted into silk fabrics and thereby established Lyons as the greatest centre of the silk industry in Europe.

RAILWAYS. By affording facilities for collecting raw materials and distributing manufactured articles, the railway has wrought many changes in centres of trade. Many places, especially in the inland parts of a country, have been called into existence by railways, and such places as St. Paul, Chicago, Buffalo and St. Louis, in the United States, and Montreal, Toronto and Winnipeg in Canada, would never have reached their present importance without the railway. The important city of Vancouver is the product of the railway.

Railways have turned our prairies into wheat-fields; and with rapid transport and "cold storage" have changed, through irrigation, the dry grounds of California into

orchards, whose fruits now are sold not only along the Atlantic sea-board and in Canada, but in Europe itself; and much of the interior trade that would have gone down the Mississippi and helped to build up St. Louis and New Orleans, they have taken to Chicago. Wherever a railway has a station there a village is sure to spring up.

POLITICAL CENTRES. The place selected as the political capital of a country or state may have little in the way of commercial advantage to commend it. Such places are usually chosen, not for the facilities which they offer for commerce, but for their central location. The fixing of the seat of government at such places usually gives a great impetus to their development, and they may become great centres, not only of population but also of trade and commerce. Ottawa, the capital of Canada, Washington, the capital of the United States, and many of the capitals of the various states of the American union in the New World, and Berlin, Vienna, Madrid and St. Petersburg in the Old, all illustrate how the growth of a place may depend upon its being the political centre of a country. Pekin, though regarded by the Chinese as one of their oldest cities, owes its importance to its becoming the capital on the conquest of China by the Mongols in A.D. 1282.

IRRIGATION.

There are vast tracts of land that we call deserts; they have no grass, no fields of grain, no forest trees, no orchards, no farmsteads, no cities. They have nothing that would invite man to take up his dwelling in them; man avoids them unless they lie between him and a point that he wishes to reach; they have no rain and no streams. But where a spring happens to burst out, there grass and trees grow, for only water is needed to make the desert fruitful. Then there are other tracts with but little water, wholly insufficient to support other than a scanty vegetation, or that support a vegetation only during a short season; such are the steppes of eastern Europe and western Asia, (pages 314, 316, etc.).

The pressure of increasing population with the demand for more land has led to the endeavor, often with the

greatest success, to supply the needed moisture. *Irrigation* has been resorted to. The floods that spread over Egypt when the Nile overflows its banks during the rainy season

Fig. 199. An Irrigation Canal, Southern Alberta.

in far away Abyssinia, are made to go much farther by means of countless little ditches, and, as said on a former page, a great dam a mile and a quarter long and a hundred and thirty feet high has been completed at Assuan, which will store up for future use a vast quantity of water that

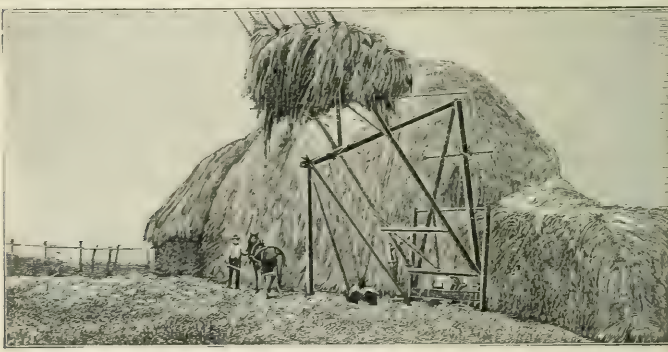


Fig. 200. Stacking Irrigated Hay, Southern Alberta.

would otherwise run into the Mediterranean. India has the most extensive system of irrigation of all countries. (Page 252).

The Moors brought irrigation into Spain when they conquered it 1,200 years ago. In dry Australia the waters of the rivers are in many places drawn off into irrigation canals. On the Goulburn River in Victoria a dam has been constructed, and from it canals, one 31 miles long and another 84, carry the water where otherwise it would not go. The Russians by the same means now raise cotton where formerly (east of the Caspian) were only dry plains.

In our own Alberta and Western Assiniboia, the driest part of the Canadian West, there are several hundred miles (469 in 1901) of irrigation canals, large and small. Even more extensively employed is irrigation in the dry regions skirting the eastern Rocky Mountains in the United States; it is almost the sole dependence for water in parts of California, especially the south, where storage dams are built often high up on the mountain-side; and Florida needs it to give water to her orange groves. Artesian wells (see page 202) serve the same purpose, and so towns and villages spring up about these artificial sources of water where otherwise none would exist.

COMMODITIES OF COMMERCE.

The commodities of commerce may be conveniently considered under the following headings:—(1) Products of the farm; (2) Products of the forest; (3) Products of the mine; (4) Products of the sea; (5) Manufactured products.

PRODUCTS OF THE FARM. A few years ago, the more thickly peopled portion of the Dominion, particularly the Province of Ontario, produced large quantities of wheat; but with the increased production of this food-stuff in the North-Western States, Argentina, and the Canadian North-West, it was found impossible to compete in the markets of the world with the farmers of these differently favored regions. In these places the farms are large and the soil is new and in general very fertile. In Manitoba and the North-West Territories, the black loamy soil rests on a substratum of clay which keeps the moisture within easy reach of the plants and so preserves them from drought. Being new, this soil is not exhausted and so crop after crop can be raised at little expense for tillage. The great size of the farms of the new regions has necessitated the universal employment of agricultural machinery, so that now the time actually spent in raising one bushel of wheat is ten minutes, whereas it used to be three hours, and the cost of production has fallen from $17\frac{3}{4}$ cents to $1\frac{1}{2}$ cents. In the older regions, the farms being

small and the soil more or less exhausted from long cropping, the farming operations must be much more varied and intensive; hence the farmers are turning their attention to dairy-farming and the raising and fattening of stock. Canada now takes a high rank for its export of horses, cattle, sheep and bacon, and is foremost in the production of cheese, every Province producing it.

The grain from the North-West is brought by rail to Fort William and thence by boat to Midland, Owen Sound or Montreal. At each of these places as well as along the railways in Manitoba and the North-West Territories, large elevators have been built to store the grain until it can be moved eastward, (Fig. 80). Much of the wheat grown in the western part of the Territories is sent westward to feed the miners of British Columbia. Its great distance from the wheat markets of the world hinders its profitable shipment east.

Large flour mills at Winnipeg, Rat Portage, Keewatin and other places where water-power is abundant, grind much wheat into flour which commands the highest price. Like the wheat, the flour is exported chiefly to Great Britain.

The other great wheat producing districts of the world are the United States, Russia in Europe, France, British India, Austria-Hungary, Argentina and Australia.

The climate and soil of Ontario, Quebec and the Maritime Provinces are well adapted for raising barley, oats, rye and peas. These are exported chiefly to Great Britain. Barley adapts itself to a great variety of climatic conditions and so can be profitably raised in many parts of the earth. The great barley-producing countries are Russia, Austria-Hungary and Germany. Oats require a cool, moist climate to bring them to perfection and hence are extensively grown in eastern Canada. Other countries which produce great quantities of oats are the United States, Russia, France, and Great Britain.

The moist climate of the Eastern part of Canada adapts it for growing hay. This cannot all be consumed at home. The greater part of the surplus is exported to the United States.

The part of Ontario which is nearly surrounded by the great lakes is the garden of Canada. In it small fruits as grapes, berries and cherries, attain an almost perfect growth, as do also plums, apples and peaches. Apples grow to great perfection in many parts of Ontario, Quebec and Nova Scotia. A large and increasing export trade in apples is carried on with Great Britain.

In British Columbia, the valleys have a mild climate, and the soil is rich with the scourings from the mountains—conditions most favorable for fruit-growing. Farmers there are turning their attention more and more to this industry. A ready market is found for the fruit in the North-West and Manitoba, where the climate is too severe for extensive culture.

Owing to the lesser degree of moisture in Western Assiniboia and Southern Alberta as compared with the rest of the North-West Territories, the prairie grasses cease to grow early in the autumn and become hay standing without being cut and cured. The grasses are so nutritive that cattle require no other food to fit them for market. The snowfall, too, is so light that cattle need little or no shelter in winter, and find most of their own food for themselves.

In the older provinces of the Dominion much attention is now given to rearing cattle, horses and sheep. Live cattle are shipped in great numbers from Montreal, Quebec and St. John to Great Britain to be slaughtered there. As yet the dressed meat industry in Canada is only in its infancy. Dressed meat is a large item in the exports of the United States, Argentina and Australia; but the export of eggs and dressed poultry to Great Britain from Ontario and Quebec is an important industry.

Canada has also become an important butter and cheese producing country, the factories and creameries being found in every Province of the Dominion.

PRODUCTS OF THE FOREST. In the eastern part of Canada there are vast areas of pine, spruce, poplar and hardwood; hence the Provinces of Ontario, Quebec, and New Brunswick produce great quantities of lumber and pulpwood. North of the region of the pine, is the sub-arctic belt of spruce and poplar, 200 or 300 miles wide, which stretches across the continent and gives Canada a greater forest area than any other lumber-producing country possesses.

In Ontario, the centres of the lumbering industry are Ottawa, Deseronto and around the shores of Georgian Bay; in Quebec, the city of Quebec; and in New Brunswick, Marysville and St. John. Most of the lumber and timber from Quebec and New Brunswick is exported to Great Britain; the United States receives most of that manufactured in Ontario.

Owing to its moist climate and its comparatively high temperature British Columbia has also vast forests. Here Douglas fir, Western white cedar, spruce and hemlock

attain a great size and grow in great profusion. Most of the lumber is manufactured from Douglas fir, and is well adapted for building purposes.

Fig. 201. Douglas firs: the smallest is nine feet in diameter.
—Edwards Bros., Phot., Vancouver.

Although the wood-pulp industry is yet only in its infancy, in 1901 pulp to the value of nearly $2,000,000 was exported from Canada.

The other timber-producing countries of the world are Russia, Sweden and Norway, Austria-Hungary and the United States. Hard woods, like walnut, maple, oak, beech and hickory, are common in the southern parts of Canada and the United States.

The ornamental woods are chiefly of tropical origin. Mahogany comes from Mexico, Central America and the West Indies; Rosewood from Brazil, Teak, so largely used in ship-building in Great Britain, from British India and Siam.

Other products of the forest as tar, turpentine and resin, are supplied by the pine of North and South Carolina and Georgia. The basin of the Amazon supplies two-thirds of all the India-rubber used by the world. The remainder is obtained from Central America, West and Central Africa and British India. Gutta Percha is the hardened milky

juice of a large tree which grows chiefly in Java, Borneo and Sumatra. Quinine, so useful in malarial fevers, is obtained from the bark of the cinchona tree. Originally a native of the northern Andes it has been introduced into Italy, Ceylon, Java and India and flourishes so well in its new home that the greater part of the quinine of commerce comes from these countries. Cork is the bark of a species of oak which flourishes in Spain, Portugal and Northern Africa, particularly in Algeria.

PRODUCTS OF THE MINE. Canada has great mineral resources but at the present time mining is only in its infancy. Within the past few years, however, this industry has made great progress, particularly in Nova Scotia, Ontario, British Columbia and the Yukon.

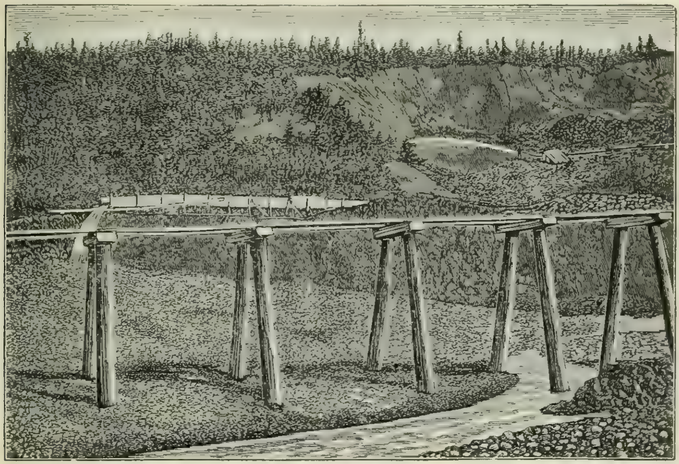


Fig. 202. Hydraulic placer mining at Cariboo, B.C.
—Edwards Bros., Phot., Vancouver.

Gold. The most valuable mineral deposit is gold, which is produced in great quantities in the Yukon district and in British Columbia, and, though to a much less extent, in Nova Scotia and near the Lake of the Woods in Ontario. Canada is now the fifth gold producing country in the world. These rank according to the value of the gold produced as follows :—British Africa, United States, Australia, Russia, Canada, Mexico and India. In 1901 Canada produced $24,462,222 of gold.

Coal. Coal is the second most important mineral product of Canada. The mines are chiefly in the northern part of Nova Scotia and in British Columbia. Coal is also found in New Brunswick and in many parts of the North-West Territories.

Nova Scotia coal finds a ready market in the cities along the coast of the northern part of the United States and in the Province of Quebec. It can be shipped at profit as far west as Montreal.

The British Columbia coal mined on Vancouver Island supplies the cities of the United States on the Pacific Coast as far south as San Francisco. That mined in the interior at Crow's Nest Pass is exported to the mining centres of Montana and places along the Great Northern railway and into the North-West Territories.

Coal is found in many parts of the world, but at the present time the great coal-producing countries are the United States, Great Britain, Western Germany, Austria-Hungary and Belgium.

Iron and Steel. Great deposits of iron ore are found in many parts of Canada. Owing to the presence of easily mined iron ore in Nova Scotia, in the western part of Newfoundland, and in some coast districts of Quebec in proximity to supplies of limestone and coal, great iron industries are being developed at New Glasgow, Londonderry, and Sydney in the northern part of Nova Scotia.

On account of the abundance of iron ore near Sault Ste. Marie in Ontario, extensive works for the production of iron and steel are in the course of erection. These works are not as favorably situated as those in Nova Scotia because of the absence of coal, which must be imported.

The most important iron-producing countries in the world are the United States, Great Britain, Germany, France, Russia, Austria-Hungary and Belgium. Sweden produces much excellent iron ore, but owing to the absence of coal, the ore is taken to Great Britain to be smelted.

Petroleum. In Canada petroleum comes almost exclusively from south-western Ontario, but there is every indication of its existence in great quantities in the North-West Territories. Along the Athabasca it is seen oozing from the banks of the river. Russia (around Baku in the Caucasian provinces) and the States of Ohio, Pennsylvania and Texas produce nearly 95 per cent. of the petroleum used in the world.

Silver. Of the silver produced by the world, the United States supplies nearly one-third, Mexico nearly as much, and Australia, Germany, Bolivia, Chili, Spain and Canada the greater portion of the remainder. In Canada both Ontario and Quebec produce some silver, but by far the greatest quantity comes from British Columbia, which now yields about $2,500,000 worth each year.

Copper. The United States produces more than half of the world's supply of copper. The remainder comes from Spain and Portugal, Chili, Japan, Germany, Australia, Mexico, Russia and Canada. It is found in Ontario and Quebec, but the greatest quantity of Canadian copper is produced by British Columbia.

Nickel. Nickel is used chiefly as an alloy of other metals in the manufacture of small implements or parts of them, small coins, etc. It greatly improves the quality of steel when used for armor plate or for various structural

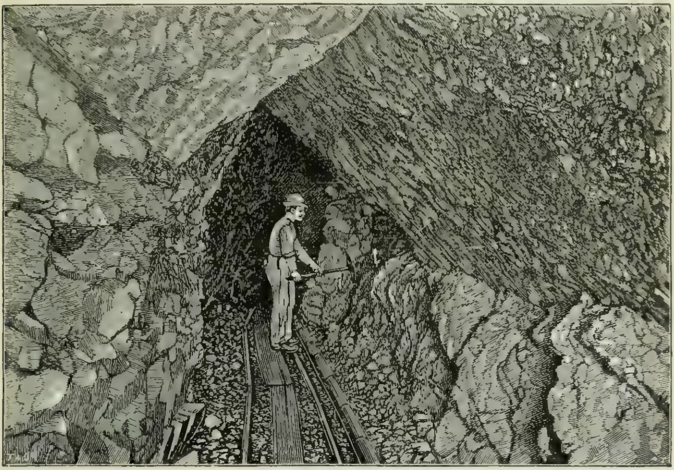


Fig. 203. Interior of Fern Mine, Nelson, B.C., 100 feet from mouth of tunnel.
—Edwards Bros., Phot., Vancouver.

purposes. The Sudbury district of Ontario and the French penal colony of New Caledonia now produce the world's supply of this metal.

Lead. British Columbia is the only province of Canada in which lead is produced in considerable quantities. It is mined as an ore of silver. In the United States it is extensively produced in the silver mining regions. Mexico and Spain also yield large quantities of this metal.

Asbestus. Asbestus is used for non-conducting packing and fire-proof material. Nearly all the asbestus in use comes from the Thetford region in Quebec.

PRODUCTS OF THE SEA.

The development of steam navigation and the use of refrigerator cars have given a great impetus to the fishing industry. Formerly fish had to be cured immediately after being caught. Now they can be sent to market in good condi-

Fig. 204. The salmon fleet of the mouth of the Fraser letting out the nets. —Courtesy of the Canadian Pacific Railway.

tion many hundreds of miles from where they were taken. As a consequence fish are much more extensively used as food than formerly.

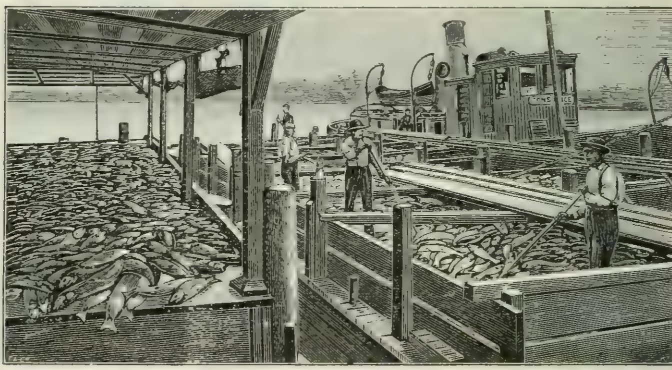


Fig. 205. Landing the newly caught salmon from scows at a cannery; 25,000 in sight. —Courtesy of Canadian Pacific Railway.

There are three great fishing centres in the world; one in the North Sea, frequented by Norwegian, British, Danish and other fishermen; one in the north-western Atlantic Ocean, frequented by Canadian, British, French and United States vessels; and one in the Northern Pacific.

The western Atlantic Ocean contains the most valuable fishing grounds in the world. The Labrador current brings to the shallow coast waters vast quantities of algæ upon which cod, mackerel, herring, shad, haddock and halibut live. The inshore fisheries of this region are also exceedingly rich in lobsters.

The Canadian fisheries are among the most important and most productive in the world. The annual value of the catch is now over $20,000,000. In addition to these are the vast areas of inland fresh water fisheries, including not only the great Laurentian Lakes and Rivers, but also the Great North-Western Lakes as well. The fish taken in the Great Lakes and rivers are chiefly whitefish, lake trout, herring, sturgeon, bass and pickerel.

On the Pacific coast all the gulfs, bays and rivers swarm with fine food fishes, such as the salmon, herring, halibut, rock-cod, &c. Salmon enter the Fraser, Naas, Skeena and other rivers in immense numbers where they are caught and canned. In 1900 the value of the salmon catch alone in British Columbia was $3,391,744.

FURS. As has been said elsewhere, the fur of fur-bearing animals is thickest and warmest where most needed,—in the cold regions of the earth, the northern part of the Eastern and the Western continent. The great centres of the fur trade are London, Leipzig (the most important) and Nijni-Novgorod in Russia.

The Hudson Bay Company still controls the fur trade of Canada. The hunters, many of whom are Indians, bring their furs to such centres as Winnipeg, Edmonton, York Factory, Moose Factory, Montreal, &c., where they are exchanged for supplies for the coming year. The most important fur-bearing animals of Canada are the beaver, marten, mink, and muskrat. Many other skins are, however, collected as those of the ermine, otter, badger, bear, deer, fox, lynx, raccoon, skunk, wolf, squirrel, &c. The most valuable furs are ermine, sable, sea-otter and seal.

Much fur is also obtained from the southern hemisphere. From the higher Andes great numbers of chinchilla skins are obtained, the soft, pearly gray fur of which is largely used in women's dresses. In Australia and New Zealand the rabbit has so greatly increased in numbers that it has become a plague, and although many million skins are annually exported, its increase is scarcely checked.

MANUFACTURED ARTICLES. In a chapter on Commercial Geography it would be impossible to consider all the various kinds of manufactures carried on even in Canada. A few of the most important will be treated under such general headings as textile products, iron and steel, pulp and paper, leather, &c.

Textile Fabrics. The raw materials for textile fabrics are chiefly cotton, wool, silk, flax, hemp and jute. The great cotton producing districts of the world are the United States, India and Egypt. The greatest centres of cotton manufacture are Liverpool and Manchester. In the United States this industry has been rapidly increasing during the past few years and now one-third of the home-grown cotton is manufactured. In Canada there are twenty-two cotton mills producing fabrics worth $12,000,000 a year. Large mills are situated at Valleyfield, Montreal, Montmorenci and Magog in the Province of Quebec; at St. John in New Brunswick; and at Hamilton in Ontario.

Woollen Fabrics. The chief wool-producing regions of the world are Australia, the Plate Basin, and South Africa. In these countries pasturage is abundant and winter feeding is rarely required. Owing to improved processes of manufacture and the increased supply of the raw material, the price of woollen fabrics has greatly declined. Leeds and London are to the woollen trade what Manchester and Liverpool are to the cotton trade.

In Canada, Ontario farmers are giving much attention to improving the quality of wool by introducing good breeds of sheep. There are 275 large centres of woollen manufacture in Canada and many minor ones.

Silk. The silk of commerce is derived from the cocoon of the silk worm. The raw material is produced chiefly in Southern China and Japan, but silk culture is highly developed in Italy and France. France is the great consumer of raw silk. Marseilles receives enormous quantities for distribution to Lyons and St. Etienne, where it is converted into silk fabrics.

Pulp and Paper. Paper is made from vegetable fibre. The great source of paper at the present day is wood pulp made from spruce or poplar. Other vegetable fibres used are linen and cotton rags, straw and esparto, the last a grass which is indigenous to Spain and Algeria.

Owing to its great abundance of spruce Canada holds a prominent place in the manufacture of pulp and paper. Large mills are found at Cornwall, Merritton, and at Sault Ste. Marie in Ontario, and at Hull, Valleyfield, Portneuf and Grand-Mère in Quebec, where wrapping, printing and writing paper are extensively manufactured. The surplus wood pulp is exported chiefly to the United States.

Leather and Leather Goods. Owing to the abundance of hemlock bark for tanning purposes, Canada has long been noted for producing good leather. The tanneries are mainly in Ontario and Quebec. Large quantities of hides for tanning are imported from South America.

Manufactures from Wood. As we have seen Canada is rich in many kinds of woods, hence manufactures of articles of wood, from matches and spools to household furniture, are made in almost every town and village of older Canada and in very many of newer Canada as well.

Iron and Steel. Manufactures of iron and steel are carried on in every part of the Dominion. At the present time Canada produces small structural iron-products and finished steel articles such as require lighter kinds of machinery in their manufacture. Mills are, however, in course of erection at Sault Ste. Marie and Sydney which will make the larger and heavier kinds of iron and steel products also. Ontario and Quebec manufacture the great bulk of such articles as stoves, castings, machinery, hardware, sewing machines, locomotives, cars, bicycles, etc.

Agricultural Implements. Almost all the agricultural implements that are exported such as ploughs, self-binding reapers, mowers, &c., are manufactured in the cities and larger towns of the Province of Ontario. A large export trade has been established with Great Britain, Australia, Germany, France and South America.

Shipbuilding. In the days of wooden vessels, St. John was a great centre for shipbuilding, but with the introduction of iron and steel ships, this industry ceased. Montreal, Toronto, Owen Sound and Collingwood are now actively engaged in shipbuilding. Toronto, especially, has a large shipyard.

Sugar Refining. Extensive sugar refineries are situated at Montreal and Halifax. The raw material, cane sugar, is imported chiefly from the West Indies.

Within the past three years, a new industry has grown up in Ontario, viz., the growing of sugar beets and their manufacture into sugar. Model factories have been erected at Berlin, Wallaceburg, Wiarton, and Dresden. At Raymond, too, in south-western Alberta the cultivation of the sugar beet has been entered upon on an extensive scale, and large sums of money have been expended in erecting the needful factories.

Canned Goods. Fruits and vegetables are extensively canned at Hamilton, Delhi, Aylmer, and many other places in Ontario.

Meat Curing. Pork-packing is carried on in Toronto, Ingersoll, Winnipeg, and other places in Canada.

Flour and Cereals. There are extensive mills at Toronto, Mount Forest, Fergus, Tillsonburg, Lindsay, Peterboro', London and Chatham.

Electric Apparatus. Factories for the manufacture of various kinds of electric apparatus are situated at Peterboro', Toronto and Montreal.

Musical Instruments. Canada manufactures nearly all the musical instruments which are used in the country and also produces a considerable number for export to Great Britain and Australia. Centres of this industry are Toronto, Woodstock, London, Guelph, Clinton and Bowmanville.

Breweries and Distilleries. There are extensive breweries at Toronto, London, Waterloo, Brockville and Perth, and large distilleries at Halifax, Toronto, Walkerville, Belleville and Waterloo.

Tobacco. Tobacco is now extensively grown in Canada. The largest manufactories are situated at Montreal, Quebec, Toronto, London and Leamington.

Rubber Goods. Rubber goods are extensively manufactured at Toronto, Montreal and Granby.

Thus we see everywhere around us man engaged in subduing nature, using nature's forces for his benefit and making animal, plant and mineral alike contribute to his needs or his desires. Where the individual alone could do little by his own unaided powers we see man in communities, or government, aiding in the ways already indicated and in many others.

Government assumes many forms in principle or in detail, but that form is best which while protecting and aiding the individual physically, morally and intellectually, leaves him the widest freedom of thought, speech and action, consistent with the welfare of the community or state in which he lives.

The Governments of Great Britain and her Colonies are the very foremost; for while nearly all the governments in civilized countries protect their subjects and foster education, trade, and manufactures, none give such full personal freedom of thought, speech and action as those do, or seek so successfully to elevate peoples of a lower civilization who have come under their control.

INDEX.

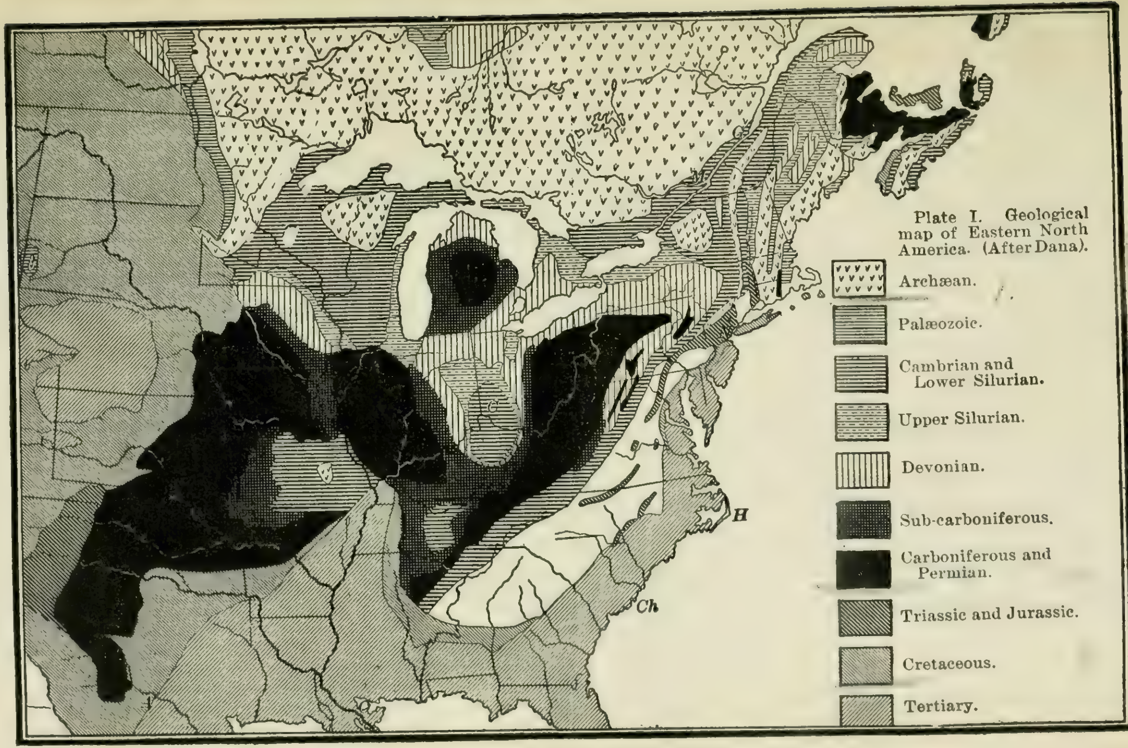
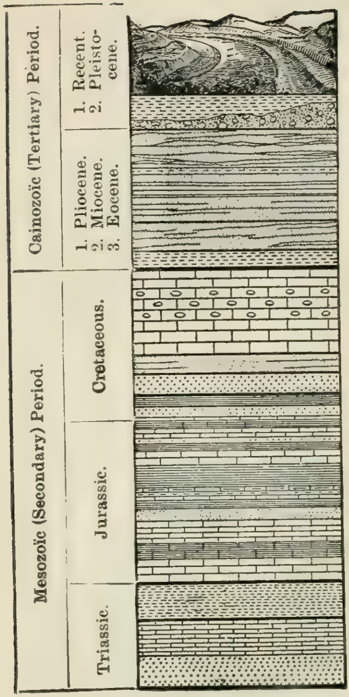


Plate I. Geological map of Eastern North America. (After Dana).



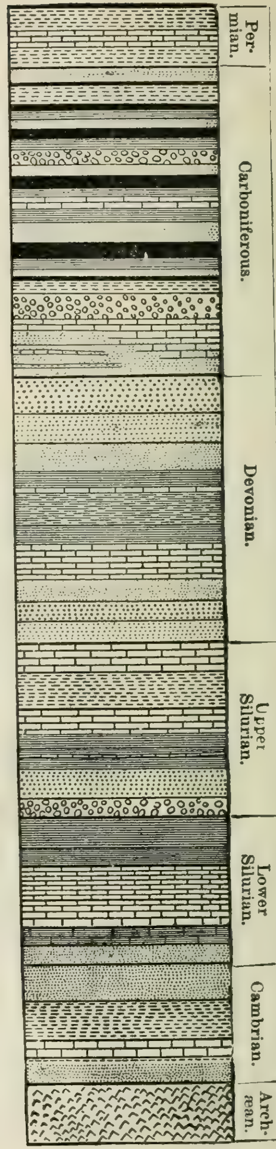
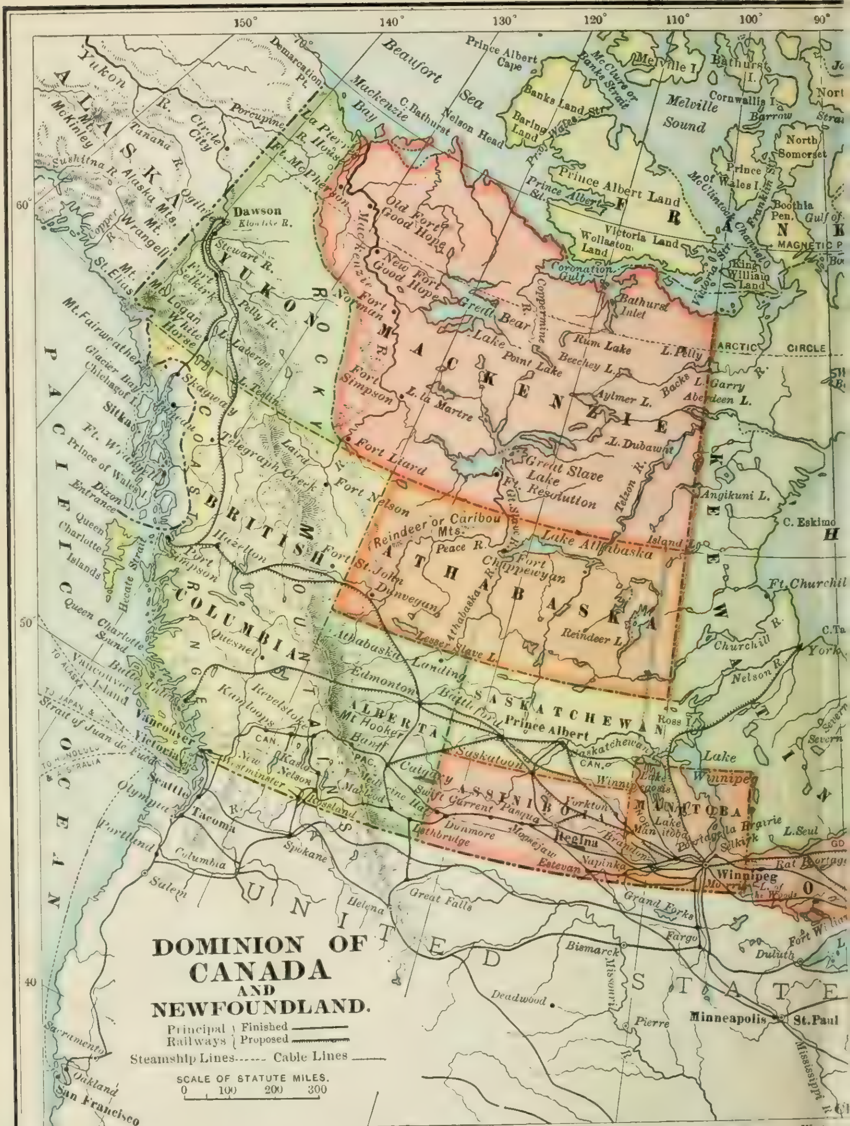


Plate II.

Chronological Order of Strata.
(After Dana).


BRITISH ISLES
Railways :
Cables :
Steamship Routes :
SCALE OF STATUTE MILES
0 50 100
Shetland Islands
Orkney Islands
Pentland Firth
Thurso
Wick
Hebrides
Moray Firth
Banff
Fraserburgh
Dingwall
Peterhead
Inverness
Aberdeen
Fort William
Stonehaven
SCOTLAND
Montrose
Dundee
Perth
Oban
Loch Lomond
Firth of Forth
Greenock
Leith
Berwick
Glasgow
Edinburgh
ATLANTIC
OCEAN
NORTH
SEA
TO QUEBEC & MONTREAL
TO NEW YORK
North Channel
Malin Head
Moville
Lough Foyle
Londonderry
Firth of Clyde
Dumfries
Newcastle
Sunderland
Durham
Carlisle
Solway Firth
Donegal
Donegal Bay
Sligo
Belfast
I. of Man
Westport
Dundalk
Irish Sea
IRELAND
L. Ree
Athlone
Dublin
Galway
Galway Bay
Limerick
Wicklow
Holyhead
Tralee
Tipperary
Mallow
Waterford
Wexford
Cork
Queenstown
Valentia
CABLE TO NORTH AMERICA
Fasnet Rock
St. George's Channel
St. Milford
Lancaster
York
Bradford
Leeds
Hull
Preston
Bolton
Salford
Liverpool
Manchester
R. Humber
Chester
Sheffield
Lincoln
The Wash
Derby
Nottingham
Norwich
Stafford
Wolverhampton
Leicester
ENGLAND
Northampton
Ipswich
Birmingham
WALES
Worcester
Cambridge
Merthyr Tydfil
Gloucester
Oxford
Swansea
Cardiff
London
R. Thames
Bristol Channel
Bristol
Dover
Salisbury
Hastings
Southampton
Brighton
Calais
Str. of Dover
Newhaven
Portsmouth
Isle of Wight
Weymouth
Falmouth
Plymouth
English Channel
Scilly Is.
Dieppe
Cherbourg
Le Havre
Channel Is.
Jersey
FRANCE
TO NEW YORK
TO SOUTH AMERICA, AFRICA, ASIA & AUSTRALIA
TO CHRISTIANIA & CHRISTIANSAND
TO TRONDHJEM
TO COPENHAGEN
TO HAMBURG
TO AMSTERDAM
TO ROTTERDAM
TO GOTHENBURG
TO SCANDINAVIAN PORTS
M.-N. WORKS, BUFFALO, N.Y.
6° Longitude West 4° from Greenwich 2°
10° 8° 6° 4° 2° 0° 2°
60° 58° 56° 54° 52° 50°


DOMINION OF
CANADA
AND
NEWFOUNDLAND.
Principal Railways Finished
Proposed
Steamship Lines
Cable Lines
SCALE OF STATUTE MILES.
0 100 200 300
Beaufort Sea
Mackenzie Bay
Prince Albert Cape
Banks Land
Baring Land
Melville I.
Bathurst I.
Melville Sound
Cornwallis I.
Barrow
North Somerset
Prince of Wales I.
Prince Albert Land
Victoria Land
Wollaston Land
Boothia Pen.
King William Land
Coronation Gulf
Bathurst Inlet
Old Fort Good Hope
New Fort Good Hope
Fort Norman
Great Bear
Point Lake
Rum Lake
L. Pelly
Beechey L.
Aylmer L.
Backs
L. Garry
Aberdeen L.
L. Dubawnt
MACKENZIE
Fort Simpson
L. la Martre
Fort Liard
Great Slave Lake
Ft. Resolution
Fort Nelson
Reindeer or Caribou Mts.
Peace R.
Fort Chippewyan
Lake Athabaska
ATHABASKA
Reindeer L.
Lesser Slave L.
Dunvegan
Fort St. John
Athabaska Landing
Edmonton
SASKATCHEWAN
Battleford
Prince Albert
Saskatoon
ALBERTA
Mt Hooker
Banff
Calgary
Medicine Hat
Macleod
Swift Current
Lethbridge
Dunmore
ASSINIBOIA
Regina
Moosejaw
Estevan
Yorkton
Brandon
MANITOBA
Lake Manitoba
Lake Winnipeg
Winnipeg
Selkirk
Portage la Prairie
KEEWATIN
Angikuni L.
C. Eskimo
Ft. Churchill
Churchill R.
York
Nelson R.
Ross I.
L. Seul
ALASKA
Yukon R.
Porcupine R.
Circle City
Mt. McKinley
Tanana R.
Sushitna R.
Alaska Mts.
Mt. Wrangell
Copper R.
Mt. St. Elias
Mt. Logan
Mt. Fairweather
Glacier Bay
Chichagof I.
Sitka
Juneau
Skagway
Ft. Wrangell
Prince of Wales I.
Dixon Entrance
Dawson
Klondike R.
Stewart R.
YUKON
Fort Selkirk
Pelly R.
White Horse
L. Laberge
L. Teslin
Ft. McPherson
La Pierre House
Telegraph Creek
Laird R.
ROCKY MOUNTAINS
BRITISH COLUMBIA
Hazelton
Port Simpson
Queen Charlotte Islands
Hecate Strait
Queen Charlotte Sound
Quesnel
Kamloops
Revelstoke
Vancouver Island
Vancouver
Victoria
Strait of Juan de Fuca
New Westminster
Kaslo
Nelson
Rossland
PACIFIC OCEAN
Seattle
Tacoma
Olympia
Portland
Columbia R.
Salem
Spokane
Helena
Great Falls
UNITED STATES
Bismarck
Missouri R.
Deadwood
Pierre
Fargo
Grand Forks
Duluth
Minneapolis
St. Paul
Mississippi R.
Sacramento
Oakland
San Francisco
Longitude West

80°
70°
60°
50°
40°
30°
C. Athol
C. York
Cobourg I.
Tasiusak
Bay
Upernivik
Bylot I.
Baffin
R. Clyde
Disko I.
Jakobshavn
Christianshaab
Godhavn
Disko Bay
GREENLAND
(To Denmark)
Holstenborg
C. Dan
Umivik
King Frederick VI Land
Davis Strait
Home Bay
C. Searle
Sukkertoppen
Godthaab
Cumberland Pen.
C. Mercy
Cumberland Sound
Fiskernæs
Frederikshaab
Mt. Kunnak
Julianehaab
Frederiksdal
C. Farewell
Fox Channel
Fox Land
Baffin Land
Southampton Island
Bell I.
Salisbury I.
Nottingham I.
Charles I.
Frobisher Bay
Resolution I.
Hudson Strait
C. Chidley
Akpatok I.
H.B.Co.
Ungava Bay
Mansfield I.
Mosquito Bay
LABRADOR
Fort Chimo
Nain
Zoar
Hopedale
C. Dufferin
King George Islands
Larch R.
Lower Seal L.
Upper Seal L.
UNGAVA
L. Melville
St. Michael Bay
TO EUROPEAN PORTS
White Bay
Notre Dame Bay
Twillingate
Henrietta Maria
Long I.
James Bay
Big R.
L. Nichicun
East Main R.
Attikonak L.
QUEBEC
Height of Land
Mingan
Strait of Belle Isle
NEWFOUNDLAND
Port au Basques
Placentia
C. Race
St. Johns
TO EUROPE
Ekwan R.
Moose Factory
Albany R.
Moisie
Anticosti I.
C. Gaspe
Gaspe Pen.
Gulf of St. Lawrence
Magdalen Is.
Grand Miquelon
St. Pierre I.
Breton I.
Sydney
Pt. Hawkesbury
C. Canso
Rimouski
Paspebiac
Chatham
Pr. Edward I.
Charlottetown
TO LIVERPOOL
Sable I.
Abitibi
L. Abitibi
L. St. John
Chicoutimi
Riviere du Loup
NEW BRUNSWICK
Moncton
Pictou
NOVA SCOTIA
Halifax
Lake Nepigon
Heron Bay
ONTARIO
Missanabie
PAC.
Quebec
Levis
Three Rivers
Sorel
Richmond
Sherbrooke
Fredericton
St. John
Bay of Fundy
Yarmouth
C. Sable
Superior
Sault Ste. Marie
North Bay
Mattawa
Montreal
Hull
St. Johns
St. Andrews
Sudbury
Parry Sound
Ottawa
Ogdensburg
Portland
Boston
C. Cod
Mackinaw
Manitoulin I.
Lake Huron
Georgian Bay
Owen Sound
Kingston
Toronto
Hamilton
L. Ontario
Niagara Falls
Rochester
Albany
Port Huron
London
L. Michigan
Milwaukee
Detroit
St. Thomas
L. Erie
Windsor
Buffalo
UNITED STATES
Long I.
New York
Cleveland
TO PHILADELPHIA
TO PANAMA
TO JAMAICA
TO BERMUDA
ATLANTIC OCEAN
60°
50°
40°
THE M.-N. WORKS BUFFALO, N.Y.
Greenwich
80°
70°


NORTH
AMERICA.
Principal Railroads Finished
Proposed
Steamship Lines
Cable Lines
SCALE OF STATUTE MILES
0 50 500 1000
NORTH POLE
ARCTIC OCEAN
PACIFIC OCEAN
ATLANTIC OCEAN
ASIA
ALASKA
GREENLAND (To Denmark)
ICELAND (To Den.)
DOMINION OF CANADA
UNITED STATES
MEXICO
CENTRAL AMERICA
SOUTH AMERICA
WEST INDIES
Hudson Bay
Gulf of Mexico
Caribbean Sea
Davis Strait
ARCTIC CIRCLE
TROPIC OF CANCER
Longitude West 90° from Greenwich

SOUTH AMERICA
Railroads : —— Steamship Routes :------
Cables :——
0 500 1000
SCALE OF STATUTE MILES
M.-N. WORKS, BUFFALO, N.Y.
Longitude West 60° from Greenwich
TROPIC OF CAPRICORN
EQUATOR
Caribbean Sea
PACIFIC OCEAN
ATLANTIC OCEAN
Jamaica (Brit.)
Haiti
Porto Rico (U.S.)
Guadeloupe (Fr.)
Martinique (Fr.)
Barbados (Brit.)
Trinidad (Brit.)
Port of Spain
Curaçao (Dutch)
Puerto Cabello
La Guaira
Caracas
Barcelona
Pt. Gallinas
Maracaibo
Sabanilla
Barranquilla
Cartagena
Colon
Panama
Gulf of Panama
Medellin
Tolima Vol.
Bogota
Ibague
Buenaventura
COLOMBIA
Popayan
Bucaramanga
Barquisimeto
VENEZUELA
Bolivar
Orinoco
Delta of the Orinoco R.
Llanos
Georgetown
Paramaribo
Cayenne
BRITISH GUIANA DUTCH FRENCH
Mouths of the Amazon R.
Quito
Chimborazo Vol.
Guayaquil
ECUADOR
Cuenca
Pt. Parina
Paita
Piura
Chiclayo
Truxillo
Huaraz
Lima
Callao
Pasco
PERU
Ayacucho
Pisco
Cuzco
Puno
Arequipa
Mollendo
Arica
Iquique
Antofagasta
Caldera
CHILE
La Serena
Aconcagua Vol.
Valparaiso
Santiago
Juan Fernandez Is.
Chillan
Concepcion
Valdivia
Puerto Montt
Chiloe I.
Chonos Archipelago
Wellington I.
Punta Arenas
Strait of Magellan
Tierra del Fuego
C. Horn
Manaos
Amazon R.
Santarem
Para (Belem)
Maranhão
Paranahiba
Ceara
C.St.Roque
Parahiba
Pernambuco
Maceio
Bahia
BRAZIL
Plateau of Brazil
Villa Bella
Matto Grosso
Cuyaba
Goyaz
Diamantina
Ouro Preto
Petropolis
Victoria
Campos
Nictheroy
Rio de Janeiro
São Paulo
Santos
Curitiba
Blumenau
Porto Alegre
Pelotas
Rio Grande do Sul
Titicaca L.
Mt. Sorata
BOLIVIA
La Paz
Oruro
Santa Cruz
Trinidad
Potosi
Sucre
Tarija
Concepcion
PARAGUAY
Asuncion
Villa Rica
Salta
Tucuman
Corrientes
Rioja
San Juan
Cordoba
Rosario
Parana
URUGUAY
Colonia
Montevideo
Buenos Aires
La Plata R.
ARGENTINA
Mendoza
Talca
Mar del Plata
Bahia Blanca
San Matias Gulf
Chubut R.
St. George Bay
Patagonia
Falkland Islands (Brit.)
Port Stanley


THE WORLD
Showing
BRITISH EMPIRE
Scales along the Equator
NAUTICAL MILES
KILOMETERS
0 500 1000 2000
0 1000 2000 3000 4000
ARCTIC OCEAN
C. Chelyuskin
RUSSIAN EMPIRE
SIBERIA
Lena R.
Arctic Circle
East C.
Bering Strait
C. Prince of Wales
ALASKA
Nome
Dawson
YUKON
MACKENZIE
DOMINION OF
Parry Is.
Banks I.
Melville Sound
Gt. Bear L.
Gt. Slave L.
ATHABASKA
Edmonton
Regina
Sitka
Queen Charlotte Is.
Vancouver I.
Victoria
Vancouver
NORTH AM
UNITED S
San Francisco
New Orleans
MEXICO
Mexico
ASIA
Irkutsk
Amur R.
Sea of Okhotsk
Bering Sea
Monday
Sunday
Aleutian Islands
CHINESE EMPIRE
Peking
Port Arthur
Dalny
Vladivostok
Kiao chau
Wei-hai-wei (Br.)
Tokio
Yokohama
JAPAN
Shanghai
Yellow Sea
Canton
Formosa
Hongkong
BURMA
Mandalay
Rangoon
FRENCH INDO-CHINA
SIAM
Bangkok
Saigon
Manila
Philippine Is. (U.S.)
Andaman Is. (Br.)
Nicobar Is.
Achin
STR. SETT.
Singapore
Sumatra
Borneo
EAST INDIES
Java
Batavia
New Guinea
Thursday I.
Palmerston
Christmas I. (Br.)
Keeling Is. (Cocos) (Br.)
Tropic of Cancer
PACIFIC OCEAN
Honolulu
Hawaii (U.S.)
MICRONESIA
MELANESIA
Palmyra I. (Br.)
Fanning I. (Br.)
Christmas I. (Br.)
Gilbert Is. (Br.)
Ellice Is. (Br.)
Phoenix Is. (Br.)
Equator
Manahiki Is. (Br.)
Union Group (Br.)
Samoa
POLYNESIA
New Hebrides (Br. Fr.)
Coral Sea
Fiji (Br.)
Tonga Is. (Br.)
Cook (Br.)
Tahiti (Fr.)
Pitcairn I. (Br.)
Tropic of Capricor
International Date Line
OCEANICA
N. W. Cape
Indian Ocean
WESTERN AUSTRALIA
SOUTH AUSTRALIA
QUEENSLAND
NEW SOUTH WALES
VICTORIA
AUSTRALIA
Brisbane
Perth
C. Leeuwin
Albany
Adelaide
Sydney
Tumut
Melbourne
TASMANIA
Hobart
Norfolk I.
Kermadec Is. (Br.)
Auckland
Wellington
NEW ZEALAND
Dunedin
Chatham Is. (Br.)
Bounty Is. (Br.)
Antipodes (Br.)
Stewart I.
Auckland Is. (Br.)
Campbell I. (Br.)
Royal Company Is. (Br.)
Macquarie I. (Br.)
ANTARCTI
THE M.-N. WORKS, BUFFALO
Longitude 120° East from 150° Greenwich
Longitude 120° West from
90° 120° 150° 180° 150° 120°
60 30 0 30 60

Franz Josef Land
Spitzbergen
GREENLAND
ARCTIC OCEAN
Nova Zembla
Kara Sea
North Cape
Baffin Bay
Jan Mayen I.
Davis Strait
Hudson Str.
Labrador
Iceland
Arctic Circle
Archangel
SIBERIA
Finland
St. Petersburg
Christiania
NORWAY
SWEDEN
C. Farewell
SCOTLAND
North Sea
BRITISH ISLES
IRELAND
Dublin
Liverpool
Hamburg
Copenhagen
Stockholm
GERMANY
Berlin
Moscow
RUSSIA
RUSSIAN EMPIRE
Tomsk
Omsk
ASIA
UNGAVA
Newfoundland
St. Johns
Valentia I.
London
Paris
FRANCE
Marseille
EUROPE
AUSTRIA HUNGARY
Vienna
Odessa
Black Sea
Caspian Sea
Aral Sea
Bokhara
Tashkend
Halifax
Rome
TURKISH EMP.
Constantinople
SPAIN
Madrid
ITALY
Naples
PORT.
Lisbon
Gibraltar
Str. of Gibraltar
Mediterranean Sea
Algiers
Malta
Cyprus
Azores (Port.)
New York
Philadelphia
Washington
ATLANTIC OCEAN
Teheran
PERSIA
Kabul
AFGH.
Jerusalem
Suez Canal
Alexandria
Cairo
EGYPT
Bahrein Is. (Br.)
BALUCH.
Lucknow
Delhi
INDIA
Calcutta
Bombay
Goa
Madras
Ceylon
Colombo
Bermudas (Br.)
Bahama Is.
WEST INDIES
St. Thomas (Dan.)
SAHARA
SUDAN
ANGLO-EGYPTIAN SPHERE
Khartum
Mecca
ARABIA
Aden (Br.)
Arabian Sea
Laccadive Is. (Br.)
Sokotra I. (Br.)
Caribbean Sea
Barbados (Br.)
Trinidad (Br.)
Georgetown
BR. GUIANA
Cape Verde Is. (Port.)
C. Verde
GAMBIA (Br.)
SIERRA LEONE (Br.)
LIBERIA
GUINEA
NIGERIA
Lagos
AFRICA
ANGLO EGYPTIAN SUDAN
ABYSSINIA
BR. SOMALI COAST
BR. EAST AFRICA
Maldive Is. (Br.)
GOLD COAST (Br.)
Gulf of Guinea
Kongo R.
KONGO STATE
Victoria Nyanza
Mombasa
Zanzibar (Br.)
Seychelles (Br.)
Amirante Is. (Br.)
Amazon R.
Para
Pernambuco
Kabinda (Port.)
St. Paul de Loanda
SOUTH AMERICA
Lima
BRAZIL
Bahia
Ascension I. (Br.)
St. Helena (Br.)
RHODESIA
Salisbury
Mozambique
Madagascar
Rodriguez I. (Br.)
Mauritius I. (Br.)
Indian Ocean
Rio de Janeiro
Walfisch Bay (Br.)
ORANGE RIV. COL.
TRANSVAAL COL.
Johannesburg
NATAL
CAPE COLONY
Cape Town
Cape of Good Hope
Valparaiso
Santiago
Montevideo
Buenos Aires
Rio de la Plata
Falkland Is. (Br.)
South Georgia (Br.)
Magellan
Cape Horn
South Orkney Is.
South Shetland Is. (Br.)
Graham Land
OCEAN
SCALE OF ENGLISH STATUTE MILES AT DIFFERENT LATITUDES
Longitude 30° East from 60° Greenwich


EUROPE
Railroads: Cables:
Steamship Lines:
0 100 200 400 600
SCALE OF STATUTE MILES
ARCTIC OCEAN
ATLANTIC OCEAN
North Sea
Black Sea
Caspian Sea
Mediterranean Sea
Bay of Biscay
English Channel
Adriatic Sea
Egean Sea
ARCTIC CIRCLE
ICELAND
Mt. Hecla
Reikiavik
NORWAY
SWEDEN
Finland
Lapland
BRITISH ISLES
IRELAND
SCOTLAND
DENMARK
FRANCE
SPAIN
PORTUGAL
GERMAN EMPIRE
AUSTRIA HUNGARY
RUSSIA
Poland
ROUMANIA
BULGARIA
SERVIA
TURKEY
GREECE
ASIA
AFRICA
Turkey in Asia
North Cape
Hammerfest
Vadso
Lofoden Is.
Faroe Is.
Shetland Is.
Orkney Is.
Hebrides
Trondhjem
Bergen
Christiania
Stockholm
Copenhagen
St. Petersburg
Archangel
White Sea
L. Ladoga
L. Onega
Riga
Valdai Hills
Moscow
Nizhni Novgorod
Kazan
Perm
Ekaterinburg
Orenburg
Omsk
Ural Mountains
Tundras
Petchora R.
Ob R.
Saratov
Astrakhan
Volga R.
Kama R.
Ural R.
Don R.
Dnieper R.
Dwina R.
Aral Sea
Sea of Azov
Crimea
Odessa
Caucasus Mts.
Mt. Elburz
Tiflis
Baku
Mt. Ararat
Teheran
Constantinople
Bosporus
Dardanelles
Smyrna
Athens
Crete
Bucharest
Balkan Mts.
Carpathian Mts.
Budapest
Vienna
Prague
Trieste
Warsaw
Berlin
Hamburg
Frankfort
Munich
Edinburgh
Glasgow
Liverpool
Dublin
Killarney
London
Paris
Brest
Bordeaux
Lyon
Marseille
Geneva
Mt. Blanc
Bern
The Alps
Milan
Venice
Genoa
Florence
Rome
Naples
Mt. Vesuvius
Appennines
Corsica
Sardinia
Sicily
Palermo
Mt. Etna
Malta (Brit.)
Balearic Is.
Barcelona
Pyrenees
Madrid
Valencia
Malaga
Cadiz
Gibraltar
Strait of Gibraltar
Lisbon
Oporto
C. Finisterre
TO NORTH AMERICA
TO NORTH AMERICA (CANADA)
CABLES TO NORTH AMERICA
TO WEST INDIES & SOUTH AMERICA
SOUTH AFRICA
TO S. AMERICA
Longitude East from Greenwich
THE M.-N. WORKS BUFFALO, N.Y.


ASIA.
Railroads
Steamship Lines
Cable Lines
SCALE OF STATUTE MILES.
0
500
1000
Longitude East from Greenwich
ARCTIC OCEAN
INDIAN OCEAN
PACIFIC OCEAN
SIBERIA
RUSSIAN EMPIRE
EUROPE
TURKISH EMPIRE
CHINESE EMPIRE
CHINA
MONGOLIA
MANCHURIA
KOREA
EMPIRE OF JAPAN
INDIA
PERSIA
ARABIA
AFRICA
TIBET
SIAM
FRENCH INDO-CHINA
CENTRAL ASIA
SUNGARIA
CHINESE TURKESTAN
RUSSIAN TURKESTAN
AFGHANISTAN
BALUCHISTAN
NEPAL
BHUTAN
OMAN
HINDUSTAN
UPPER BURMA
LOWER BURMA
London
Paris
Berlin
Hamburg
Vienna
Rome
Naples
Marseille
St. Petersburg
Moscow
Constantinople
Smyrna
Trebizond
Damascus
Jerusalem
Mt. Sinai
Mecca
Mocha
Aden
Cairo
Alexandria
Bagdad
Teheran
Tabriz
Bushire
Kabul
Khelat
Karachi
Maskat
Bombay
Delhi
Lahore
Lucknow
Benares
Calcutta
Hyderabad
Madras
Colombo
Ceylon
Mandalay
Rangoon
Bangkok
Saigon
Hanoi
Hue
Singapore
Georgetown
Peking
Tientsin
Shanghai
Canton
Hongkong
Nanking
Hankau
Lanchau
Singanfu
Chengtu
Tokio
Yokohama
Nagasaki
Osaka
Vladivostok
Khabarovsk
Irkutsk
Tomsk
Omsk
Tobolsk
Yakutsk
Samarkand
Tashkend
Bokhara
Khiva
Yarkand
Lassa
Caspian Sea
Black Sea
Mediterranean Sea
Arabian Sea
Bay of Bengal
Persian Gulf
Bering Sea
Okhotsk Sea
Japan Sea
Yellow Sea
Eastern Sea
China Sea
Aral Sea
Lake Baikal
Lake Balkash
Ural Mountains
Caucasus Mts.
Himalaya Mts.
Hindu Kush Mts.
Kuenlun Mts.
Yablonoi Mts.
Stanavoi Mts.
Mt. Everest
Desert of Gobi
Kirghiz Steppes
Tundras
ARCTIC CIRCLE
TROPIC OF CANCER
EQUATOR
U. S. CABLE
Philippine Islands (To U.S.)
Aleutian Islands (To U.S.)
Guam (To U.S.)
Ladrone Islands
Kurile Islands
Sakhalin Island
Formosa
Luzon I.
Mindanao I.
Borneo
Celebes
New Guinea
Sumatra
Hainan
Cyprus
Crete
Nova Zembla
New Siberia Islands
North Cape
East Cape
Kamchatka
Yezo
Nipon
Liukiu Is.
British Isles
North Sea
Suez Canal
Strait of Bab-el-Mandeb
Gulf of Aden
C. Guardafui
C. Comorin
C. Cambodia
Strait of Malakka
Malay Peninsula
Gulf of Siam
TO VANCOUVER
TO SEATTLE
TO PORTLAND
TO SAN FRANCISCO
TO AFRICAN PORTS
TO AFRICA
TO AUSTRALIA

AFRICA
Railroads: Finished / Proposed
Cables: Steamship Lines:
SCALE OF STATUTE MILES
0 500 1000
Longitude 30° West from 20° Greenwich 10°
40° Longitude 50° East from 60° Greenwich 70°
M.-N. WORKS, BUFFALO, N.Y.
ATLANTIC OCEAN
INDIAN OCEAN
EQUATOR
TROPIC OF CANCER
TROPIC OF CAPRICORN
Mediterranean Sea
Red Sea
Arabian Sea
ASIA
ARABIA
INDIA
SPAIN
ITALY
GREECE
Crete
Str. of Gibraltar
Madeira Is. (Port.)
Canary Is. (Span.)
Cape Verde Is. (Port.)
Ascension Is. (Brit.)
St. Helena (Brit.)
Annobon I. (Span.)
St. Thomas I. (Port.)
Fernando Po I. (Span.)
Sokotra (Brit.)
C. Guardafui
Seychelles Is. (Brit.)
Amirante Is. (Brit.)
Comoro Is. (Fr.)
MADAGASCAR (Fr.)
Reunion I. (Fr.)
Mauritius I. (Brit.)
Rodriguez I. (Brit.)
MOROCCO
ALGERIA
TUNIS
TRIPOLI
BARCA
EGYPT
SAHARA
SUDAN
SENEGAL
GAMBIA
PORTUGUESE GUINEA
FRENCH GUINEA
SIERRA LEONE
LIBERIA
IVORY COAST
GOLD COAST
DAHOMEY
NIGERIA
KAMERUN
SPAN.
FRENCH CONGO
CONGO STATE
LOWER GUINEA
ANGOLA (Portuguese West Africa)
GERMAN SOUTH-WEST AFRICA
BECHUANA-LAND
RHODESIA
TRANSVAAL
ORANGE RIV.
NATAL
BASUTOLAND
CAPE COLONY
PORTUGUESE EAST AFRICA
GERMAN EAST AFRICA
BRITISH EAST AFRICA
ABYSSINIA
ERITREA
FRENCH SOMALILAND
BRIT. SOMALILAND
ITALIAN SOMALILAND
ANGLO-EGYPTIAN SUDAN
Anglo-Egyptian Sphere of Influence
Libyan Desert
Nubia
Darfur
Wadai
Bagirmi
L. Chad
Victoria Nyanza
L. Tanganyika
L. Nyassa
L. Bangweolo
Victoria Falls
Zambezi
Nile
Niger R.
Senegal R.
Congo
Uganda
Orange R.
Tangier
Fez
Morocco
Algiers
Constantine
Biskra
Tunis
Sfax
Tripoli
Alexandria
Cairo
Port Said
Suez Canal
Isthmus of Suez
Assuan
Suakin
Massawa
Aden
Jibuti
Berbera
Kassala
Khartum
Omdurman
New Dongola
Fashoda
Adis Ababa
Taudeni
Timbuktu
Say
St. Louis
C. Verde
Bathurst
Freetown
Monrovia
Kumassi
Abomey
Abbeokuta
Lagos
Buea
Libreville
Stanley Pool
Kabinda (Port.)
Boma
Leopoldville
Loanda
Benguela
Mossamedes
Walfisch Bay (Brit.)
Windhoek
Port Nolloth
Cape Town
C. of Good Hope
Port Elizabeth
Bloemfontein
Kimberley
Mafeking
Johannesburg
Pretoria
Pietermaritzburg
Durban
Lourenco Marquez
Delagoa Bay
Bulawayo
Salisbury
Beira
Mozambique
Majanga
Tananarivo
Zanzibar
Dar-es-Salaam
Mombasa
Bombay
TO WEST INDIES
TO S. AMERICA
TO HONGKONG
TO CEYLON
TO AUSTRALIA
FROM LISBON
FROM ANTWERP
FROM HAMBURG TO CAPE TOWN
HAMBURG TO DURBAN
SOUTHAMPTON TO DURBAN
FROM LONDON TO DELAGOA BAY
FROM MARSEILLES
FROM HAMBURG
FROM LONDON

columbus asia

Turkey (asia minor syria palestine Persian Coast arabia) Sultan

Arabia (aden Br.)

persia abs. Mon.) Shah

Afghanistan (absolute am

Beluchastan Br. pro.

India Br. col.

Nepal. ind State } Himalaya

Bhutan " "

Burma Br. col.

Malay, Strait settlement Br. Pro

Siam abs. Mon.

French Indo china (col & Prot)

China (Tibet) abs mon.

Korea, Jap. prot.

Japan responsible government

Russia (in asia) Siberia Turkestan

Holland owns Sumatra Java

Lesser Sunda west Timor

Celebes most Borneo, Moluccas

Brt. North Borneo Sudan

Portugal East Timor

U. S. Philippines

climate includes
temp.
rainfall
winds

constant trades
prevailing antitrades
periodical [illegible]
variable.

earth is in perihelion when nearest the sun
" " aphelion " farthest from " "

32 - Origin of oceans
33 [illegible]
34 continental shelf.
35 Deep sea deposit, sea level, temp.
36 . waves
37. Tides, causes, daily, spring & neap.
movement, height, bore, falls
38 . Currents causes
39 . warm currents
40 [illegible]
41 atmosphere, composition, importance
42 . [illegible]
43 - [illegible]
44 - height
[illegible]
- isobars